UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

REVISED DRAFT

HUMAN HEALTH RISK ASSESSMENT AND

REMEDIAL INVESTIGATION REPORT

CARSON RIVER MERCURY SITE

Prepared by

Sean Hogan, EPA Project Manager

and

Stanford Smucker, Ph.D., EPA Toxicologist

U.S. Environmental Protection Agency, Region 9

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TABLE OF CONTENTS

Section		Page
	Executive Summary	viii
1.0	Introduction	1
2.0	Scope and Approach for the Risk Assessment	3
	2.1 Risk Assessment Methodology	3
	2.2 Risk Assessment Approach	5
3.0	Site Background	6
	3.1 Site Definition	6
	3.2 Site History	6
	3.3 Site Physiography	7
	3.4 Climate	8
	3.5 Demographics	8
	3.6 Land Use	8
	3.7 Water Use	9
4.0	Conceptual Model of Sources and Areas of Deposition	10
	4.1 Contaminants of Concern	10
	4.2 Sources	10
	4.3 Release Mechanisms from Sources	11
	4.4 Transport Mechanisms	11
	4.5 Areas of Deposition and Accumulation	12
5.0	Characterization of the Areas and Populations of Potential Concern	14
	5.1 Lyon County	18
	5.1.1 Areas of Potential Concern	18
	5.1.2 Potentially Exposed Populations	22
	5.2 Storey County	25
	5.2.1 Areas of Potential Concern	25
	5.2.2 Potentially Exposed Populations	28
	5.3 Churchill County	29
	5.3.1 Areas of Potential Concern	29
	5.3.2 Potentially Exposed Populations	33
	5.4 Washoe County	34
	5.4.1 Areas of Potential Concern	34
	5.4.2 Potentially Exposed Populations	36

TABLE OF CONTENTS CONT'D

Section		Page
6.0	Summary of Remedial Investigation.	37
	6.1 Sampling Objectives.	37
	6.2 Data Collection Strategy and Methods to Evaluate Data	37
	6.2.1 Identify Contaminants of Potential Concern.	37
	6.2.2 Estimate Exposure Point Concentrations.	41
	6.2.3 Characterize Mercury Levels in Soil At and Around Historic Millsites.	53
	6.3 Data Evaluation and Quality Assurance/Quality Control Methods.	58
7.0	Exposure Assessment.	59
	7.1 Identification of Exposure Pathways.	59
	7.1.1 Exposure Routes of Potential Concern.	60
	7.1.2 Potentially Complete Exposure Pathways.	62
	7.1.3 Screening and Selection of Exposure Pathways for Evaluation.	62
	7.2 Evaluation of Exposure Pathways.	62
	7.2.1 Equations for Quantitatively Evaluating Exposure Pathways.	63
	7.2.2 Intake Parameters.	67
	7.2.3 Quantitative Evaluation of Chronic Daily Intake.	70
	7.2.4 Adjustment of Chronic Daily Intakes.	71
8.0	Toxicity Assessment.	77
	8.1 Toxicity Assessment of Carcinogenic Effects.	77
	8.2 Toxicity Assessment of Noncarcinogenic Effects.	78
	8.2.1 Chronic Effects.	78
	8.2.2 Short Term Effects.	78
	8.3 Dose-Response Relationships.	79
	8.3.1 Mercury.	79
	8.3.2 Arsenic.	82
9.0	Risk Characterization.	84
	9.1 Approach to Estimate Human Health Risks.	84
	9.1.1 Noncarcinogenic Hazard Estimation.	84
	9.1.2 Lifetime Excess Cancer Risk Estimation.	85
	9.2 Characterization of Health Risks	90
	9.2.1 Noncarcinogenic Health Risks for Residents Living Near Historic Millsites.	90
	9.2.2 Carcinogenic Health Risks for Residents Living Near Historic Millsites.	92

TABLE OF CONTENTS CONT'D

Section	Page
9.2.3 Noncarcinogenic Health Risks for Residents Living on the Alluvial Fan.	93
9.2.4 Carcinogenic Health Risks for Residents Living on the Alluvial Fan. .	94
9.2.5 Noncarcinogenic Health Risks for Residents Living on the Flood Plain.	95
9.2.6 Carcinogenic Health Risks for Residents Living on the Flood Plain. .	96
9.2.7 Noncarcinogenic Health Risks for Individuals Who Consume Fish from the Carson River System and Washoe Lake .	96
9.2.8 Noncarcinogenic Health Risks for Individuals Who Consume Waterfowl from Carson Lake and Stillwater Areas.	98
9.2.9 Noncarcinogenic Risks for Individuals Who Consume Tule Bulbs from Carson Lake.	99
9.3 Characterization of Future Risks.	99
9.4 Risk Uncertainty.	100
10.0 Potential Lead Exposure.	100
10.1 Perspectives on the EPA Blood "Level of Concern". . . .	103
10.2 Lead Exposure Assumptions.	103
10.3 Results.	105
11.0 Conclusions.	107
References.	109
Appendix A: Comstock Mills.	121
Appendix B: Data Tables	128
Appendix C: Cowherd Particulate Emission Factor Equation.	169
Appendix D: Potentially Complete Exposure Pathways.	170
Appendix E: Chronic Daily Intake Equations and Parameters.	179
Appendix F: Input Parameters for EPA UBK Lead Model.	186
Appendix G: Derivation of Site-Specific Cleanup Goal for Mercury in Residential Soils.	187
Appendix H: Data Validation Reports	

LIST OF TABLES

Table		Page
4.1	Summary of Release and Transport Mechanisms and Areas of Deposition.	13
5.1	Populations of Potential Concern.	16
5.2	General Location of the Areas of Potential Concern.	17
5.3	Current Land Use for Areas of Potential Concern in Lyon County.	22
5.4	Racial Makeup for Counties Intersected by CRMS Study Area.	23
5.5	Age Distribution for Counties Intersected by CRMS Study Area.	23
5.6	Projected Growth Rates for Counties Intersected by CRMS Study Area.	24
5.7	Current Land Use for Areas of Potential Concern in Churchill County.	33
6.1	Mercury Speciation in Soils, Samples Analyzed by EPA EMSL-LV.	39
6.2	Identification of Contaminants of Potential Concern.	40
6.3	Indicator Fish Species for Exposure Assessment.	52
6.4	Summary of Exposure Point Concentrations for Mercury.	54
6.6	Summary of Exposure Point Concentrations for Arsenic.	57
7.1	Exposure Routes of Concern.	60
7.2	Selection of Pathways for Quantitative Evaluation.	64
7.3	Pathway Specific Chronic Daily Intake Estimates for Mercury.	72
7.4	Chronic Daily Intake Estimates for Fruit and Vegetables.	74
7.5	Pathway Specific Chronic Daily Intake Estimates for Arsenic (Non-caner).	75
7.6	Pathway Specific Chronic Daily Intake Estimates for Arsenic (Caner).	76
8.1	EPA Derived Reference Doses and Reference Concentrations.	80
9.1	Pathway Specific Hazard Quotients for Mercury.	86
9.2	Pathway Specific Hazard Quotients for Arsenic (Non-cancer).	88
9.3	Pathway Specific Hazard Quotients for Arsenic (Cancer).	89
9.4	Potential Hazard Indices for Residents Near Millsites.	91
9.5	Potential Cumulative Hazard Indices for Residents Near Millsites.	92
9.6	Potential Carcinogenic Risks for Residents Near Millsites.	93
9.7	Potential Hazard Indices for Residents on the Alluvial Fan.	94
9.8	Potential Carcinogenic Risks for Residents on the Alluvial Fan.	95
9.9	Potential Hazard Indices for Residents on the Carson River Flood Plain.	96
9.10	Potential Hazard Indices for Individuals Who Consume Fish from the Carson River System.	98

LIST OF TABLES cont'd

Table		Page
9.11	Potential Hazard Indices for Individuals Who Consume Waterfowl from the Carson River System.	98
9.12	Summary of Site Specific Uncertainties Associated with Risk Estimates.	101
9.13	Summary of General Uncertainties Associated with Risk Estimates.	102
10.1	Calculated Blood Lead and Lead Uptakes for Children.	106
A.1	Comstock Mills.	121
B.1	Assignment of Sample ID Numbers to Mills.	128
B.2	Mercury Speciation Samples Analyzed by Oak Ridge Research Inst.	132
B.3	Mercury Speciation Samples Analyzed by EPA EMSL-LV.	133
B.4	Total Mercury in Surface Soils: Historic Millsites and Extant Tailing Piles.	134
B.5	Total Arsenic in Surface Soils: Historic Millsites and Extant Tailing Piles.	138
B.6	Total Lead in Surface Soils: Historic Millsites and Extant Tailing Piles.	140
B.7	Total Mercury in Surface Soils: Alluvial Fan, Flood Plain, Washoe Lake and Pleasant Valley.	142
B.8	Total Arsenic in Surface Soils: Alluvial Fan and Flood Plain.	144
B.9	Total Lead in Surface Soils: Alluvial Fan and Flood Plain.	145
B.10	Total Mercury in Subsurface Soils.	146
B.11	Concentrations of Select Trace Metals Measured in Soil Samples from Lahontan Reservoir Beach Areas.	148
B.12	Concentrations of Select Trace Metals Measured in Surface Soil Samples from Indian Lakes Beach Areas.	150
B.13	Total Mercury in Surface Soils: Subareas.	151
B.14	Total Mercury in Sediments: Carson River System and Washoe Lake.	154
B.15	Total Mercury, Arsenic and Lead in Drinking Water.	156
B.16	Total Mercury, Arsenic and Lead in Lahontan Reservoir Surface Water.	157
B.17	Total Mercury: Indoor Air.	158
B.18	Total Mercury: Vegetables, Fruit, and Root Soil.	160
B.19	Total Mercury in Bullrush Roots.	162

LIST OF TABLES cont'd

Table		Page
B.20	Total Mercury: Muscle Tissue of White Bass Collected from Washoe Lake and the Carson River System.	164
B.21	Total Mercury: Muscle Tissue of Shoveler Ducks .	167
B.22	Total Mercury: Muscle Tissue of Mallards.	168
B.21	Total Mercury: Muscle Tissue of Green Wing Teal.	168
D.1	Potentially Complete Exposure Pathways for Lyon County.	170
D.2	Potentially Complete Exposure Pathways for Storey County.	173
D.3	Potentially Complete Exposure Pathways for Churchill County and the South Valley of Washoe County.	176
E.1	Intake Parameters for Soil Ingestion.	180
E.2	Intake Parameters for Inhalation.	181
E.3	Typical Intake Parameters for Ingestion of Locally-Grown Vegetables.	182
E.4	High-end Intake Parameters for Ingestion of Locally-Grown Vegetables.	183
E.5	Angler Statistics for Churchill County.	184
E.6	Intake Parameters for Consumption of Fish.	185
E.7	Intake Parameters for Consumption of Waterfowl.	185

LIST OF FIGURES

Figure #	
1	Carson River Mercury Site Study Area
2	Carson River Basin Hydrographic Areas
3	Locations of Historic Comstock Mills
4	Washoe Process Flow Diagram
5	Land Use, CRMS Study Area
6	Land Use, CRMS Study Area (Western Region)
7	Population Distribution, CRMS Study Area
8	Population Distribution, CRMS Study Area (Western Region)
9	Soil Sampling Locations, Dayton
10	Sub-areas of Potential Concern, Dayton
11	Soil Sampling Locations, Alluvial Fan and Flood Plain
12	Soil Sampling Locations, Below Lahontan Dam
13	Soil Sampling Locations, Lahontan Reservoir Recreation Area
14	Soil Sampling Locations, Washoe Lake Recreation Area
15	Groundwater and Air Sampling Locations in Dayton
16	Groundwater Sampling Locations in Mark Twain
17	Garden Sampling Locations
18	Soil Sampling Locations, Silver City
19	Soil Sampling Locations, Gold Hill and American Flat
20	Soil Sampling Locations, Virginia City
21	Soil Sampling Locations, Sixmile Canyon
22	Soil Sampling Locations, Flood Plain between New Empire and Dayton
23	Sub-areas of Potential Concern, Silver City
24	Sub-areas of Potential Concern, Gold Hill and American Flat
25	Sub-area of Potential Concern, Virginia City
26	Sub-areas of Potential Concern, Sixmile Canyon
27	Sub-areas of Potential Concern, Flood Plain between New Empire and Dayton
28	Sub-areas of Potential Concern Below Lahontan Dam
29	Process for Selecting Exposure Pathways
30	Probability Density Function for Blood Lead (Dayton)

EXECUTIVE SUMMARY

Introduction

This Human Health Risk Assessment/Remedial Investigation report ("HHRA") presents the findings from the field investigations conducted by EPA during the months of May through October 1993 and August 1994, as part of the Carson River Mercury Site (CRMS) Remedial Investigation and Feasibility Study (RI/FS). Based on these findings and data from other sources, potential human health risks posed by mercury, arsenic, and lead detected in soil, sediments, surface water, ground water, and biota in the Carson River System and Washoe Valley are assessed. Estimates of the potential severity of human health effects from releases of heavy metals was accomplished following the general guidelines of the Risk Assessment Guidance for Superfund (EPA, 1989). This included evaluating the concentrations of trace metals measured in the environment, their environmental fate and transport, their toxicology, and the degree of human exposure to those chemicals. Risk to human health is quantitatively characterized based on the level of the contaminants in the environment, the estimated level of exposure to the contaminants of concern, and the toxicity of those chemicals. This HHRA is only intended to help determine what actions are necessary to reduce risks and not to fully characterize site risks or eliminate all uncertainty.

Site Definition

The Carson River Mercury Site (CRMS) includes areas in the Carson River basin and Washoe Valley which are impacted by trace metals, particularly mercury, released and concentrated in the environment as a consequence of milling practices during the Comstock era (1859 - 1900). Impacted areas include: sediments in the Carson River beginning near Carson City, Nevada and extending downstream through the Lahontan Reservoir to the terminal wetlands in the Carson Desert (Stillwater National Wildlife Refuge, Carson Lake, and Indian Lakes); tailing piles, sediment and soil in Gold Canyon, Sixmile Canyon, and Sevenmile Canyon; and sediment and soil in Washoe Valley. Environmental media which are affected include soil, sediment, surface water, and biota. The trace metals found to be of potential concern are mercury, arsenic, and lead.

Summary of Remedial Investigation

The objectives of this phase of the remedial investigation were as follows:

- identify the contaminants of potential concern (COPC),

- estimate exposure point concentrations for potentially complete exposure pathways, and
- characterize mercury levels at and around historic millsites.

The remedial investigation activities associated with each of these objectives are described herein.

Identify Contaminants of Potential Concern

In order to determine if other trace metals occur at levels of concern, approximately 10% of the soil samples (119 samples) were analyzed for all of the trace metals included in EPA's "Target Analyte List (TAL)." Contaminants of potential concern were identified by a two step process. The first step compared the maximum detected concentration in surface soils with EPA's preliminary remediation goal (PRG). Those trace metals exceeding their respective PRG were retained for the second step which compared the arithmetic mean of the concentrations detected at historic millsites and extant tailing piles with the estimated background level for the trace metal. If this mean concentration exceeded the background level, then the trace metal was identified as a COPC. In addition to mercury, arsenic and lead were identified as COPCs by this process.

In assessing the hazards from mercury in a particular environment, it is not enough to know the form in which mercury entered that environment because various transformations can take place. The major forms of mercury which have been identified to date are methyl-mercury, elemental mercury, and mercuric mercury. As part of the effort to identify contaminants of potential concern, soil samples were analyzed to determine the species of mercury generally occurring in soil. These results determined that less than 10% of the total mercury in soils is mercuric chloride or soluble mercury and approximately 90% of the mercury is either mercuric sulfide or elemental mercury. Mercury occurring in fish and waterfowl was assumed to be 100%.

Estimate Exposure Point Concentrations

The exposure point concentration is an estimate of the concentration of the COPC that is contacted via an exposure pathway (i.e., ingestion of soil) over a given period of time. In order to estimate exposure point concentrations for potentially complete exposure pathways, samples were collected from media potentially affected by mercury (i.e., soil, air and water) in areas where mercury contamination was suspected to occur. The majority of this environmental sampling was conducted in Dayton where it was assumed that there are the highest levels of mercury occurring in a populated area. This assumption was primarily based on the fact that there were several historic millsites located in and around Dayton. Also, because Dayton is located at the mouth of Gold Canyon and on the flood plain of the Carson River, tailings could be deposited in and around Dayton from other upgradient source areas. Samples were collected from soil, ground water, air, and domestic produce; and exposure point concentrations were derived from the arithmetic mean and the associated 95 percent upper confidence limit (95 UCL). If the data set was insufficient to calculate the 95 UCL, the maximum detected value was used as the exposure point concentration. Soil samples were also collected from Sixmile Canyon, Gold Canyon, the alluvial fan below Sixmile Canyon, the Carson River flood plain, the beach areas of Lahontan Reservoir, Washoe Lake, and Indian Lakes; and exposure point concentrations were derived to represent the level of contamination in these areas. Exposure point concentrations were also derived for muscle tissue from fish and waterfowl using data from other sources.

Characterize and Assess Historic Millsites

Among the areas where mercury was thought to occur, it was assumed that the highest levels of mercury would occur at and around historic millsites and extant tailing piles. The basis for this assumption is that there would be minimal dilution caused by transport. Thus, the remedial investigation included an exhaustive research effort to identify the Comstock mills and map the millsites. Out of this research, the location of 131 mills were identified and the area of these millsites were mapped (see Figure 3). At each of the millsites, 5 to 25 surface soil samples were collected to evaluate if levels of mercury, arsenic, and lead were significant. Although subsurface soil was also sampled at millsites, the main objective was to evaluate whether incidental ingestion of surface soil was an exposure pathway of concern at the millsites. Surface soil samples were collected at locations where mercury was thought likely to occur (i.e., tailing piles, tailing ponds, ruins, etc.,).

The significance of mercury contamination was evaluated by comparing mercury levels with EPA's site specific Preliminary Remediation Goal (PRG) for soil which is 25 mg/kg. Sampling areas where there were no sample results greater than or equal to 25 ppm were screened out of further evaluation. Sampling areas where there were more than two sampling locations equal to or greater than 25 ppm were evaluated by defining a subarea with the sampling results equal to or greater than 25 ppm and determing the arithmetic mean using the data included in this subarea. Subareas were not defined for sampling areas where there was only one or two samples equal to or greater than 25 ppm, unless the sample(s) could be grouped with an adjacent subarea. Also, if two adjacent samples equal to or greater than 25 ppm, a line between the two points was buffered to create a subarea. Through this process, 39 subareas were selected for further evaluation.

Exposure Assessment

The purpose for the exposure assessment is to characterize and evaluate the signficance of potentially complete exposure pathways. A complete exposure pathway includes the following four elements: 1) a source and mechanism of chemical release, 2) retention or transport medium, 3) a point of human contact or exposure point, and 4) an exposure route (i.e., ingestion, inhalation, or dermal contact) at the contact point. Exposure pathways that were evaluated for the COPCs are described in Table ES-1.

TABLE ES-1: Exposure Pathways Evaluated for the Contaminants of Potential Concern

Exposure Pathway	**Contaminant of Potential Concern**		
	Mercury	**Arsenic**	**Lead**
Incidental soil ingestion	yes	yes	yes
Incidental sediment ingestion	yes	yes	no
Incidental surface water ingestion	yes	yes	no
Ground water ingestion	yes	yes	yes
Fish consumption	yes	no	no
Waterfowl consumption	yes	no	no
Air inhalation	yes	yes	yes

Ingestion of ground water, surface water and sediment were screened out of the exposure assessment because the COPCs were detected at relatively low levels in these media. The other exposure pathways were evaluated by estimating the chronic daily intake (CDI) of the COPCs for each pathway. The CDI is determined by multiplying the exposure point concentration by the intake factor for that medium.

The estimated CDI of mercury and arsenic via incidental soil ingestion was adjusted to reflect the degree to which metal species are available for absorption following ingestion. The estimated CDI of mercury via incidental soil ingestion was multiplied by 0.28 to reflect the degree to which mercury species are available for absorption following ingestion. Based on mercury species data developed for the CRMS, it was assumed that approximately 90% of the mercury in soil is mercuric sulfide (HgS) and 10% is mercuric chloride ($HgCl_2$). This was considered a conservative assumption given that the mercuric chloride component was generally less than 10%. Using 15% as the oral absorption value for mercuric chloride and 3% for mercuric sulfide, an oral absorption factor of 0.28 was derived ((3/15 x 0.90) + (15/15 x 0.10) = 0.28). The estimated CDI of arsenic via incidental soil ingestion was multiplied by 0.80 to reflect the degree to which arsenic is assumed to be available for absorption.

Toxicity Evaluation

The toxicity assessment weighs available evidence regarding the potential for particular chemicals to cause adverse effects in exposed individuals (weight-of-evidence), and quantitatively characterizes the relationship between the extent of exposure to an agent and the increase likelihood and/or severity of adverse effects (dose-response assessment).

The toxicity assessment evaluates noncancer effects using reference doses (RfD) as numeric indicators of toxicity. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. The oral RfD which was used to evaluate exposure via ingestion to both inorganic and organic mercury is 0.3 ug/kg-day. Because there is an ongoing debate as to whether the RfD for methyl mercury is sufficiently health protective for unborn or young children in critical stages of development, this RfD was not used to evaluate exposure via fish consumption for children and pregnant or nursing mothers. The reference concentration (RfC) used to evaluate exposure to mercury via inhalation is 0.3 ug/m^3. The oral RfD which was used to evaluate exposure to arsenic via ingestion is 0.3 ug/kg-day. The RfDs and RfC were obtained from the Integrated Risk Information System (IRIS) updated through June 1993 and the Health Effects Assessment Summary Tables (HEAST) updated through March 1993.

EPA withdrew the established RfD for lead in 1989. This was done because 1) there is not a discernible threshold for health effects related to lead exposure and 2) there are numerous environmental sources of lead which have to be considered in estimating lead exposure. In lieu of the RfD, it was determined that blood levels, which can be correlated with toxic effects, provide the best index for evaluating lead exposure. The blood lead "level of concern" is 10 ug/dL.

The toxicity assessment evaluates cancer effects based on the assumption that cancer can occur at any exposure level ("no-threshold"). EPA use the linear multistage model for extrapolating cancer risks from high dose levels, where cancer responses can be measured, to relatively low dose levels, which are of concern in the environment. This dose-response extrapolation is known as a cancer slope factor (CSF) which is used to estimate lifetime cancer risks associated with chronic low-level exposures to contaminants. The CSFs were also obtained from the Integrated Risk Information System (IRIS) updated through June 1993 and the Health Effects Assessment Summary Tables (HEAST) updated through March 1993.

Risk Characterization

Risk characterization combines the exposure and toxicity assessments to produce quantitative estimates of risk from the chemicals of potential concern. EPA evaluated the noncancer and cancer health risks associated with each of the complete exposure pathways.

Estimates of noncancer health risks are calculated by dividing the estimated chemical-specific CDI (ug/kg-day) by the respective RfD (ug/kg-day). This ratio is referred to as a "Hazard Quotient (HQ = CDI/RfD)." The sum of HQs for multiple chemicals and pathways is the "Hazard Index (HI)." EPA suggests that a HI greater than one indicates that the associated exposure scenario has a potential to result in adverse noncancer health effects and additional evaluation may be necessary. Although the potential for adverse health effects increases as the HI value increases, the level of concern does not increase linearly. This is because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects.

Noncancer health risks associated with lead are quantitatively characterized with the EPA Lead Uptake/Biokinetic Model, Version 0.5 ("UBK Model"). The UBK model was designed to estimate the blood lead levels in children 0 to 6 years of age, based on multi-media lead exposures. The model accounts for the potential environmental and maternal sources of lead (air, diet, drinking water, dust, soil, and the lead concentration in the mother's blood during gestation) for which numerous fundamental assumptions are used.

Cancer risks which are described as the incremental probability that an individual will develop cancer in their lifetime are estimated by multiplying the estimated chemical-specific CDI by the respective cancer slope factor (CSF). The cancer risk range of 10^{-4} to 10^{-6} is established as generally acceptable by EPA. In other words, the probability that one additional person out of 10,000 to 1,000,000 could develop cancer as a result of their exposure is considered an acceptable risk.

The estimated HIs and probability of cancer risks are summarized in Tables ES-2 through ES-6.

Uncertainty Assessment

It must be recognized that the assessment of cancer risks and noncancer hazards by available (generally indirect) methods can provide only crude estimates of risk and this should be borne in mind in making regulatory decisions about permissible exposure concentrations in environmental media.

EPA evaluated the uncertainty of the risk assessment and identified elements of the risk assessment that would tend to overestimate or underestimate potential exposure and risk to individuals within the study area. Risk uncertainties specific to this HHRA are summarized in Table ES.7.

TABLE ES-2: Estimated Hazard Indices for Individuals Living On or Adjacent to Impacted Areas			
Exposure Pathway	**Contaminant**	**Typical Estimate[1]**	**High-end Estimate[2]**
Soil Ingestion[3]	Mercury	0.09	2.80
	Arsenic	0.05	1.23
Dust and/or Vapor Inhalation	Mercury	0.10	0.38
	Arsenic	0.002	0.007
Consumption of Domestic Produce	Mercury	0.40	0.80
Hazard Index		0.64	5.22

1. Typical estimate is for an adult.
2. High-end estimate is for a young child (<6 years).
3. Chronic daily intake (CDI) was estimated based on mercury levels measured in surface soil at the MS004 sample area in Dayton.

TABLE ES-3: Estimated Hazard Indices for Recreational Land Use In and Around Impacted Areas			
Exposure Pathway	**Contaminant**	**Typical Estimate[1]**	**High-end Estimate**
Soil Ingestion[2]	Mercury	0.01	0.24
	Arsenic	0.002	0.10
Dust and/or Vapor Inhalation	Mercury	0.002	0.016
	Arsenic	0.00003	0.0003
Hazard Index		0.01	0.36

1. Both the typical and high-end estimates are for a school age child (7 - 18 years of age).
2. Chronic daily intake (CDI) was estimated based on mercury levels measured in surface soil at the TP007 sample area in Sixmile Canyon.

TABLE ES-4: Estimated Hazard Indices for Consumption of Fish and Waterfowl			
Indicator Species/Location	**Contaminant**	**Typical Estimate[1]**	**High-end Estimate**
White Bass/Carson River Above Lahontan	Mercury	3.5	6.5
Walleye/Lahontan Reservoir	Mercury	2.6	4.9
White Bass/Carson River Below Lahontan	Mercury	1.1	2.1
White Bass/Indian Lakes	Mercury	2.2	4.1
White Bass/Washoe Lake	Mercury	0.6	1.2
Shovelers/Carson Lake	Mercury	1.4	2.0
Shovelers/Stillwater	Mercury	0.5	0.8
Mallards/Carson Lake	Mercury	0.3	0.6
Mallards/Stillwater	Mercury	0.2	0.5

1. Both typical and high-end estimates are for an adult.

TABLE ES-5: Potential Cancer Risks for Individuals Living On or Adjacent to Impacted Area			
Exposure Pathway	**Contaminant**	**Typical Estimate[1]**	**High-end Estimate**
Soil Ingestion[2]	Arsenic	3 E-6	4 E-5
Dust and/or Vapor Inhalation	Arsenic	1 E-6	4 E-6
Cancer Risk		4 E-6	4 E-5

1. Both the typical and high-end estimates are for an adult (life-time resident).
2. Chronic daily intake (CDI) was estimated based on arsenic levels measured in surface soil in Dayton.

TABLE ES-6: Potential Cancer Risks for Recreational Landuse in Impacted Areas			
Exposure Pathway	**Contaminant**	**Typical Estimate**	**High-end Estimate**
Soil Ingestion[2]	Arsenic	4 E-8	1 E-5
Dust and/or Vapor Inhalation	Arsenic	2 E-8	2 E-7
Cancer Risk		6 E-8	1 E-5

1. Both the typical and high-end estimates are for a school-age child (7 - 18 years).
2. Chronic daily intake (CDI) was estimated based on arsenic levels measured in surface soil in Sixmile Canyon.

TABLE ES-7: Summary of Site Specific Uncertainties Associated with Risk Estimates		
Uncertainty Factor	**Effect of Uncertainty**	**Comment**
Exposure point concentrations used for volatile mercury.	May over- or underestimate risk	Exposure point concentrations used for volatile mercury were derived from the method detection limit and were not actually measured. Therefore, levels of volatile mercury in indoor and ambient air may actually be more or less than the exposure point concentration.
Exposure point concentrations for mercury levels in surface soil on the alluvial fan.	May overestimate risk	Exposure point concentrations used to evaluate incidental ingestion of soil on the alluvial fan were derived from a data set which included samples from the area of transport where tailings from Sixmile Canyon are deposited. Current residential areas on the alluvial fan are north of the area of transport. Mercury levels measured in samples collected from current residential areas did not exceed 25 mg/kg.
Exposure point concentrations for mercury levels in surface soil on the flood plain.	May overestimate risk	Exposure point concentrations used to evaluate incidental ingestion of soil on the flood plain were derived from the highest concentrations detected on the flood plain. The 95 UCL for all of the samples collected from the flood plain (18.20 mg/kg) is a factor of 20 less than the value used to estimate the high-end risks for this scenario.
Use of an indicator species to estimate mercury exposure associated with consumption of fish and waterfowl.	May overestimate risk	To the extent that the actual diets include lesser contaminated fish and waterfowl, the indicator species approach used in this HHRA is likely to overestimate exposures.
Arsenic which was identified in tailings and at historic millsites was not measured in fruit and vegetables.	May underestimate risk	Arsenic can also be taken up by plants.
Cancer slope factors for arsenic	May overestimate risks	Slope factors are based on a 95th percent UCL derived from a linearized model. Considered unlikely to underestimate risks.
Cancer risk estimates assume there is no threshold.	May overestimate risks	Possibility that some threshold exists.
Reference doses (RfDs) for mercuric mercury are derived from animal studies.	May over- or underestimate risks	Extrapolation from an animal to human may induce error because of differences in absorption, pharmacokinetics, target organs, enzymes, and population variability.

Conclusions

The conclusions of the HHRA are as follows:

- The contaminants of potential concern (COPCs) for the Carson River Mercury Site (CRMS) are *mercury, arsenic* and *lead*. Mercury was imported to the region during the Comstock era (1859 - 1900) to process ore. Although mercury is also naturally occurring in the region, such sources are not considered important relative to the large amount of mercury imported to the region during the Comstock era. Arsenic and lead are naturally occurring trace metals in the region which were concentrated in the environment by natural and anthropogenic processes.

- The highest concentrations of the COPCs are found at and around historic millsites and extant tailing piles. The COPCs also occur in areas where discharged tailings and other eroded material from historic millsites have come to be deposited. These areas include: the alluvial fan below Sixmile Canyon, the flood plain of the Carson River below New Empire, the active channel of the Carson River below New Empire, Lahontan Reservoir, Carson Lake, Stillwater, Indian Lakes and Washoe Lake.

- Although the soil ingestion pathway is important for all of the COPCs, the significance of this pathway varies according to the land use (i.e., residential, occupational and recreational) and according to the concentration of the COPC in surface soil. For residential land use, mercury and arsenic were detected in surface soil at levels which translate into a HI>1 for a young child (< 6 years of age). For recreational or open land use areas (i.e., Brunswick, Sixmile Canyon, Gold Canyon, Lahontan Reservoir, Indian Lakes, and Washoe Lake beach areas), none of the COPCs were found to occur in surface soil at levels which are considered significant for this exposure pathway.

- Inhalation of airborne contaminants does not appear to be an exposure pathway of concern for any of the COPCs irrespective of the land use scenario (HI<1).

- Ingestion of ground water does not appear to be an exposure pathway of concern for any of the COPCs.

- Incidental ingestion of surface water and sediment while swimming does not appear to be an exposure pathway of concern for any of the COPCs.

- Consumption of produce grown in contaminated soil was found to be a complete exposure pathway for mercury. However, this pathway does not appear to be of concern (HI<1).

- Individuals who consume fish or waterfowl from the Carson River system should be cautioned that the risks are proportional to the amount and type of fish and waterfowl consumed. Using an indicator species approach, typical HI estimates for selected indicator species were found to exceed 1 for the consumption of white bass from the Carson River above and below Lahontan Reservoir and Indian Lakes; and for consumption of walleye from Lahontan Reservoir. Also using an indicator species approach, typical HI estimates were found to exceed 1 for the consumption of shovelers from the Carson Lake area. Because fish and waterfowl from the Carson River system are contaminated with mercury, it is recommended that pregnant or nursing mothers and young children (< 6 years) not consume fish or waterfowl from this drainage.

1.0 INTRODUCTION

This Human Health Risk Assessment (HHRA) characterizes the potential current and future public health implications associated with mercury, arsenic, and lead detected in soil, sediment, surface water, ground water, and biota in the Carson River basin and Washoe Valley. This HHRA was developed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), 42 U.S.C. Section 9601 et seq., and in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R. Section 300 et seq., ("NCP"). The HHRA follows the basic procedures outlined in the following guidance documents:

- Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final, EPA/540/1-89/002, December 1989;

- Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim, EPA Publication 9285.7-01B, December 1991; and

- Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA, Interim Final, EPA/540/G-89/004, October 1988.

This HHRA is part of the remedial investigation and feasibility study (RI/FS) for the Carson River Mercury Site (CRMS) which is being conducted in two phases (operable units). The focus of the first operable unit (OU-1) is to characterize and assess the human health risks associated with mercury contamination in the Carson basin and in Washoe Valley, develop health based action levels for soil, and to characterize mercury levels in soil at and around historic millsites. The focus of the second operable unit (OU-2) is to characterize and assess ecological impacts and risks associated with the present levels of mercury in the sediment and surface water of the Carson River system above Lahontan Dam; and evaluate methods to reduce mercury levels in biota to levels which are ecologically protective and comply with Food and Drug Administration action levels in angler fish (1 mg/kg wet weight methyl mercury). Given that the remedial investigation for OU-1 was mostly related to characterizing and assessing human health risks, this HHRA also serves as the remedial investigation report for OU-1. The overall approach and the general sampling strategy for the CRMS RI/FS is provided in the following documents:

- Remedial Investigation and Feasibility Study Work Plan for the Carson River Mercury Site, February 1994, Ecology and Environment, Inc.; and

- Field Sampling Plan, Phase I of the Remedial Investigation and Feasibility Study for the Carson River Mercury Site, dated October 16, 1992, Ecology and Environment, Inc..

In addition to the data and information developed as part of this phase of the RI, this HHRA also incorporates and builds on data and information from other studies. The data and information from past and other ongoing studies which was used for planning this RI/FS and was used for this HHRA is provided in the following document:

- Conceptual Site Model, Carson River Mercury Site Remedial Investigation and Feasibility Study, dated September 17, 1991, Ecology and Environment, Inc..

This HHRA also applies information and data from the following sources:

- Health Effects Study for Dayton, Nevada, Prepared by Nevada State Department of Health; and

- Preliminary Health Assessment for the Carson River Mercury Site in Lyon, Churchill, and Storey Counties, Nevada, September 30, 1991, Agency for Toxic Substances and Disease Registry.

The purpose of this HHRA is to characterize the current and potential threats to human health that may be posed by contaminants migrating to ground water or surface water, releasing to air, leaching through soil, remaining in the soil, and bioaccumulating in the food chain. This HHRA is only to help determine what actions are necessary to reduce risks, and not to fully characterize site risks or eliminate all uncertainty.

2.0 SCOPE AND APPROACH FOR THE RISK ASSESSMENT

2.1 RISK ASSESSMENT METHODOLOGY

This HHRA follows the procedures described in the Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final, EPA/540/1-89/002, December 1989 ("RAGS").

This guidance provides the following procedures as a basic framework for the HHRA:

- identification of the hazardous wastes or hazardous substances present in the environment ("selection of the chemicals of potential concern");

- assessment of exposure, including a characterization of the environmental fate and transport mechanisms for the hazardous waste and hazardous substances present ("estimate levels of human exposure");

- assessment of the toxicity of the hazardous wastes or substances present ("toxicity assessment"); and

- characterization of human health risks.

The purpose for each of these steps is as follows:

Select Chemicals of Potential Concern: The purpose for this step is to select the chemicals which will be used in the quantitative risk assessment. Based on data gathered for all media from the area of concern, the chemicals of potential concern are selected based primarily on: (1) levels in the environment; (2) toxicity of the chemical; and (3) fate, transport and persistence in the environment.

Estimate Levels of Human Exposure: The purpose for this step is to estimate human exposure to the chemicals of potential concern by ingestion, inhalation, and/or external adsorption. Human exposure is estimated using the following information:

- the potential pathways by which a human receptor in the area of concern might be exposed to indicator chemicals;

- the location and biological characteristics of maximum exposed individuals (MEI) and the reasonable maximum exposed individuals (RMEI) for each potentially significant exposure pathway in the area of concern;

- demographic, land use, and climate information for the area of concern; and

- the exposure point concentration for the chemicals of potential concern in environmental transport media (i.e., soil, air, water, etc.,).

With this information, the intake of the chemical(s) of concern is calculated and expressed as the amount of substance taken into the body per unit body weight per unit time.

Toxicity Assessment: The purpose for the toxicity assessment is to weigh available evidence regarding the potential for chemical(s) of concern to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects. The toxicity assessment involves the following two steps:

- hazard identification: this is the process of determining whether exposure to the chemical(s) of potential concern can cause an increase in the incidence of a particular adverse health effect and whether the adverse health effect is likely to occur in humans; and

- dose-response evaluation: this is the process of quantitatively evaluating the toxicity information and characterizing the relationship between the dose of the contaminant administered or received and the incidence of adverse health effects in the exposed individual.

Human Health Risk Characterization: The purpose for this step is to integrate the exposure estimates and the toxicity data for the chemicals of concern and quantitatively and/or qualitatively evaluate the risks. To characterize potential noncarcinogenic effects, the projected intakes of the chemical(s) of concern are compared with acceptable intake levels which are derived from chemical specific dose response data (i.e., Reference Dose). Major assumptions, scientific judgements, and to the extent possible, estimates of the uncertainties embodied in the assessment are also incorporated into the risk characterization.

2.2 RISK ASSESSMENT APPROACH

Due to the size of the CRMS and the large number of communities potentially affected by mercury released during the Comstock era, the approach for this HHRA was to characterize the risks for the maximum exposed population and evaluate other populations of potential concern based on these findings. The approach used for this HHRA is as follows:

- survey all of the towns and communities potentially affected by mercury contamination in the Carson Basin and Washoe Valley and select the populations with the greatest potential for exposure to mercury due to proximity to mercury contamination in the environment and/or land use;

- characterize and evaluate the exposure pathways for these populations according to worst case scenarios; and

- based on the findings from this evaluation, assess the risks for all of the populations of potential concern.

If there are exposure pathways which are unique to a particular population, then these exposure pathways are characterized and evaluated separately.

The rationale for assessing the human health risks for the entire CRMS based on selected populations of potential concern is as follows:

- mercury is the principle contaminant of concern for all of the areas of potential concern;

- the significant exposure pathway for humans (i.e., ingestion) is the same for all of the areas of potential concern; and

- demographics and land use for the areas of potential concern are generally similar.

The procedure and information used to identify significant exposure pathways and the populations of concern is provided in Section 7 of this HHRA.

3.0 SITE BACKGROUND

3.1 SITE DEFINITION

The Carson River Mercury Site (CRMS) consists of the portions of the Carson drainage and Washoe Valley in Northwestern Nevada which are affected by mercury released from milling operations during the Comstock Lode. The exact boundaries of the affected area were not defined as part of this remedial investigation because knowledge of these boundaries are considered to have little or no influence on the findings described in this report.

The current definition of the CRMS study area is as follows: sediments in an approximately 70-mile stretch of the Carson River beginning near Carson City, Nevada and extending downstream through the Lahontan Reservoir to the terminal wetlands in the Carson Desert (Stillwater National Wildlife Refuge and Carson Lake); tailing piles, sediments and soil in Gold Canyon, Sixmile Canyon, and Sevenmile Canyon; and sediments and soil in Washoe Valley (Figure 1).

3.2 SITE HISTORY

Mining in the Carson River drainage basin commenced in 1850 when placer gold deposits were discovered near Dayton at the mouth of Gold Canyon. Throughout the 1850s, mining consisted of working placer deposits for gold in Gold Canyon and Sixmile Canyon. These ore deposits became known as the Comstock Lode.

The initial ore discovered was extremely rich in gold and silver; gold was more abundant in Gold Canyon while silver was more abundant in Sixmile Canyon (Smith, 1943). The early mining methods concentrated on exposing as much of the lode as was possible in wide trenches. Throughout 1859, ore was shipped to San Francisco for processing. After local ore processing began in 1860, most major mines operated their own mills, but there were also a large number of private mills. Initial ore processing techniques were slow and inefficient and a fair amount of trial and error experimenting went into the development of an effective ore-processing technique. Refinements were aimed primarily at increasing the speed of gold and silver recovery, increasing the percentage of gold and silver recovered, and decreasing the amount of gold and silver discarded in tailings piles. The general milling process employed before 1900 involved pulverizing ore with stamp mills, creating a slurry, and adding mercury to the mixture. The mercury forms an amalgam with the precious metals which is then separated from the solution and retorted. After 1900, cyanide leaching and flotation processes replaced amalgamation.

Gold and silver production from the Comstock Lode increased slowly during the early years and 1863 was the first year of large production. Throughout the remainder of the 1860s and most of the 1870s, production remained high as rich ore bodies continued to be discovered at progressively deeper depths. The bottom of the lode was abruptly reached in 1877 at a depth of about 1,650 feet, and 1878 was the first year of dramatically reduced production. Between 1877 and 1878, ore production dropped from 562,519 tons to 272,909 tons and the total value decreased from $36,301,536 to $19,661,394. In 1879, production and value dropped even further. In 1901, the first cyanide-leaching operation began in Sixmile Canyon. Cyanide leaching was capable of recovering more gold and silver from lower-grade material than was possible by amalgamation methods, and during the early 1900s mining operations consisted of mining lower-grade material and reworking former ore dumps and tailings piles. Between approximately 1920 and 1950, large tonnages of low-grade ores were mined (Bonham, 1969). Since approximately 1950, mining operations have been extremely limited in scope. Currently, two mining operations are located within the Sixmile Canyon drainage.

3.3 SITE PHYSIOGRAPHY

The Carson River drainage basin drains approximately 3,980 square miles in east-central California and west-central Nevada. The Carson River heads in the eastern Sierra Nevada mountains south of Lake Tahoe and generally flows northeastward and eastward to the Carson Sink (see Figure 1). The Carson River flows through a series of generally separate alluvial valleys from the headwaters area to the Carson Sink. In downstream order, the alluvial valleys passed by the river include Carson Valley, Eagle Valley, Dayton Plains, Stagecoach Valley, Churchill Valley, and Carson Desert (see Figure 2). Between New Empire and Dayton the river flows through a narrow, high-gradient stretch along which large ore-processing mills were situated during the late 1800s. The flow of the river is interrupted west of Fallon by Lahontan Reservoir, which was constructed in 1915 as part of the Newlands Irrigation Project. Below Lahontan Dam, flow is routed through a complex network of ditches, drains, and canals of the Newlands Irrigation Project. Irrigation return flow eventually discharges to Carson Lake, the Stillwater Wildlife Refuge, and/or the Carson Sink.

Stream flow in the Carson River above Lahontan Reservoir is highly seasonal. The major source of water for the Carson River is the winter snowpack in the Sierra Nevada mountains. Base flow is reached in late summer (August, September, and October) and flow then increases slightly through the fall and winter (November through March), until the snowmelt season starts in early spring. Maximum annual flow typically occurs in April, May and June.

The areal extent of water bodies and wetlands in the Carson Basin is highly variable, both seasonally and from year to year. This is especially true in the Carson Desert. For example, between July 1984 and February 1985, following three unusually wet years, the water surface area of the Carson Sink was approximately 200,000 acres (Rowe and Hoffman, in press), yet by April 1988 (during a second consecutive drought year) the sink was dry (Hoffman, 1988).

Washoe Valley lies between the Carson Mountain Range and the Virginia Mountain Range which separates Washoe Valley from the Carson Basin (see Figure 1). There are two water bodies in Washoe Valley, Washoe Lake and Little Washoe Lake. Most runoff in Washoe Valley drains the eastern slope of the Carson Range. Franktown and Ophir Creeks provide the bulk of the surface runoff that reaches Washoe and Little Washoe Lakes. Steamboat Creek, flowing from Washoe Valley, and Brown's Creek and Galen Creek, comprise the bulk of the surface water resources for Pleasant Valley.

3.4 CLIMATE

The climate of the region is dry due to the "rain shadow effect" created by the Sierra Nevada Mountains which form the western boundary of the region. Average annual precipitation throughout the Carson River drainage basin ranges from between 25 to 50 inches in the headwaters area in the Sierra Nevada Mountains to between 4 and 5 inches near Lahontan Reservoir and Carson Desert (Twiss et. al., 1971).

3.5 DEMOGRAPHICS

The Carson River Mercury Site intersects Carson City, Lyon County, Storey County, Churchill County, and Washoe County. According to the 1990 census taken by the Department of Commerce, U.S. Bureau of the Census, the population of the counties which are intersected by CRMS are as follows: Lyon County (population 20,001), Storey County (population 2,526), Churchill County (population 17,938), and the South Valley of Washoe County (population 4,596). Additional demographic information is provided in Section 5.0.

3.6 LAND USE

Historical land use in the Carson River basin was mostly agriculture and mining in the 1840s and '50s. The mining industry and population in the basin fell rapidly in the 1880s; however, railroad access to other markets helped promote ranching and farming. Another change in land use was an increase in irrigated acreage in the Carson Desert prompted by the impoundment of Lahontan Reservoir in 1915 and the creation of the Newlands Irrigation Project. Alfalfa is the principal irrigated crop, in terms of acreage and revenue, in the Newlands Irrigation Project. The estimated irrigated acreage ranged from 61,000 to 67,000 acres for the Newlands Project during 1980-87 (U.S. Bureau of Reclamation, 1980). Dayton and Churchill Valleys, which have the smallest populations in the Nevada portion of the Carson basin, are primarily rangeland, with agricultural areas along the Carson River. Land use and population remained relatively unchanged in the Carson River basin from 1890 until 1950, with the advent of suburban development. Since 1950, Carson City, Fallon, and rural populations have grown considerably with most of the urban and suburban development occurring on land that was previously used for agriculture (either irrigated cropland or rangeland). Presently, the local economy and urban land use are dominated by the retail trade and service sectors, primarily casinos and adjunct businesses such as hotels, motels, and restaurants that cater to tourists (Nevada Commission on Economic Development, 1985).

Land use is further described for the separate counties in Section 5.0.

3.7 WATER USE

Major water bodies in the Carson basin include the Carson River, Lahontan Reservoir, Carson Lake, the Stillwater National Wildlife Refuge, and temporary lakes, reservoirs, and alkali flats in the Carson Desert. Lahontan Reservoir is the main storage reservoir for the Truckee Carson Irrigation District (TCID). Use of surface water include: (1) agriculture irrigation; (2) maintenance of waterfowl and fishery habitats; (3) recreational use by the public such as hunting, fishing, birdwatching, swimming, and camping; and (4) to a limited extent, municipal and light-industrial purposes. Public drinking water systems are only supplied by aquifers and not by the Carson River.

In Washoe Valley there are two water bodies, Little Washoe Lake and Washoe Lake. Little Washoe Lake is used primarily for recreation (i.e. windsurfing). Big Washoe Lake is an intermittent lake which provides waterfowl and fishery habitats when it contains water and provides recreational use by public. Public drinking water systems are only supplied by aquifers and not directly by the lakes in Washoe Valley.

Water use for the different counties intersected by the CRMS is further described in Section 5.0, Exposed Populations.

4.0 CONCEPTUAL MODEL OF SOURCES AND RECEIVING MEDIA

The Carson River Mercury Site, Conceptual Site Model Report, dated September 17, 1991 prepared by E&E for EPA provides a detailed description of the occurrence and dynamics of mercury at the site to the extent possible with the data available at that time. This report was developed in order to consolidate all existing data into a working conceptual model of the site which could be used to develop an approach for characterizing the site. This subsection of the HHRA provides a summary of the Conceptual Site Model Report.

4.1 CONTAMINANTS OF CONCERN

Elevated mercury levels in the Carson River drainage basin were discovered in the early 1970s when sampling conducted by the U.S. Geological Survey (USGS) revealed elevated levels in river sediment and unfiltered surface water from the Carson River downstream from pre-1900 ore milling sites (Van Denburgh, 1973). Subsequent studies by a number of investigators (Richins, 1973; Richins and Risser, 1975; Cooper, 1983; Cooper et. al., 1985; Hoffman et. al., 1990) have further delineated the extent of mercury in river and lake sediment and water. Based largely on the information presented in these studies, the Carson River below New Empire was added to the National Priorities List (NPL) due to the widespread occurrence of mercury.

4.2 SOURCES

Sources of mercury in the Carson drainage basin and Washoe Valley include mercury imported during the Comstock era and potentially, naturally occurring mercury. There is insufficient information to characterize the full extent and significance of naturally occurring sources of mercury in the Carson drainage basin and Washoe Valley. However, according to reports which characterize the geology of the Carson River drainage basin (Thompson, 1956; Bonham, 1969; and Moore, 1969), naturally occurring deposits of mercury of economic importance do not exist in the basin. Less significant natural occurrences of mercury can be associated with mineralized zones and hot springs deposits. Although it is possible that there are such natural occurrences of mercury in the region, such sources are not considered important relative to the large amount of mercury imported to the region during the Comstock era.

Mercury imported to region during the Comstock era was purchased by mills for processing gold and silver ore. These mills employed various processes to amalgamate gold and silver. All of these processes included pulverizing the ore with stamps; creating an amalgam by mixing the crushed ore, salt, and elemental mercury into a slurry; separating the impregnated amalgam; and, finally, separating the gold and silver from the mercury with a retort. It is estimated that 186 such mills operated during the Comstock era (Ansari, 1989).

4.3 RELEASE MECHANISMS FROM SOURCES

The most widely used ore-processing method during the Comstock era was the "Washoe Process" which is described in Figure 4 (Smith , 1943). With this process, the raw ore is wet crushed with stamps, the crushed ore is separated from the slurry in a settling tank and then the crushed ore is charged with mercury (approximately 10 percent of the weight of the ore) (Smith, 1943)) in the amalgamation pan. The amalgam is separated from the slurry and the silver and gold is separated from the amalgam with a retort. The potential mechanisms by which mercury was released to environment are also indicated in Figure 4. It is thought that the majority of the mercury released to the environment was associated with tailings which were separated from the amalgam slurry and discharged into the drainage. Other possible release mechanisms would have included air emissions from the retort, fugitive air emissions throughout the process, and spilling throughout the process where mercury was handled. It is estimated that the loss of mercury exceeded 1 pound for each ton of ore milled which equals approximately 14,000,000 pounds of mercury (Smith 1943).

4.4 TRANSPORT MECHANISMS

Potential migration pathways for mercury through the CRMS include surface water, groundwater, soil, and air. Transport mechanisms are as follows:

- fluvial transport of mercury laden sediment and soil,
- fluvial transport of dissolved mercury,
- air transport of particulate mercury,
- air transport of volatile mercury, and
- percolation of elemental mercury and/or amalgam.

Fluvial transport is considered the most important mecahnism for distributing mercury throughout the Carson Drainage and Washoe Valley. This is because mill tailings are considered the most significant release mechanism and this material is easily transported by fluvial processes. Eolian transport mechanisms may also account for the widespread dispersion of mercury in the region. The fate and transport of gaseous mercury emissions to the atmsophere is not well defined, however, it is believed that gaseous mercury was released to the environment from mills while operating and that mercury evasion is presently occurring. Also included as a transport mechanism is percolation which refers to the vertical movement of mercury through the subsurface. This transport mechanism would account for the vertical movement of elemental mercury or amalgam that was released to the environment. Table 4.1 summarizes the release and transport mechanisms and the areas where mercury is potentially deposited and accumulating ("areas of potential concern").

4.5 AREAS OF DEPOSITION AND ACCUMULATION

For the purpose of characterizing and assessing human exposure at the CRMS, areas of deposition and accumulation were broken out and assessed separately. These areas and how they are defined for the purpose of this report are as follows:

Millsites/Tailing Piles: refers to the locations of the historic millsites and all associated features (i.e., tailing piles, tailing ponds, flumes, etc.) which are recognized as the original point sources of mercury in the drainage;

Tributaries: refers to the tributaries which drain the Virginia Mountain Range into the Carson basin and Washoe Valley (i.e., Six Mile Canyon, Gold Canyon, etc.,);

Alluvial Fan: refers to the alluvial fan below the mouth of Sixmile Canyon;

Flood Plain: refers to the Carson River floodplain beginning above New Empire and extending to the terminal wetlands;

Carson River: refers to the main channel of the Carson River beginning above New Empire and extending to the terminal wetlands;

TABLE 4.1: SUMMARY OF RELEASE MECHANISMS, TRANSPORT MECHANISMS AND DEPOSITION AREAS

RELEASE MECHANISM	TRANSPORT MECHANISM	DEPOSITION AREAS
Tailings Discharge	Fluvial	Millsites
Spills	Eolian	Tributaries
Retort Emissions	Percolation	Alluvial fan
Fugitive Air Emissions		Flood Plain
		Carson River
		Lahontan Reservoir
		Carson Lake
		Stillwater Wildlife Management Area
		Indian Lakes
		Washoe Lake

Lahontan Reservoir: refers to Lahontan Reservoir which has a surface area of approximately 4,856 acres (EPA, 1977);

Carson Lake: refers to Carson Lake which occupies approximately 5,600 acres (Hoffman et. al., 1990);

Stillwater Wildlife Management Area: refers to the Stillwater Wildlife management area which occupies approximately 9,600 acres during an average water year (Hoffman et. al., 1990);

Indian Lakes: refers to the Indian Lakes recreation area which have a total surface area of approximately 549 acres during an average water year (Tuttle, 1992); and

Washoe Lake: refers to the combined area of Little and Big Washoe Lake which have a combined area of approximately 5,100 acres during a normal water year (Washoe County, 1992).

Additional information regarding these areas is provided in Section 5.0.

5.0 CHARACTERIZATION OF THE AREAS AND POPULATIONS OF POTENTIAL CONCERN

The purpose for this section is to generally describe the physical characteristics and land use for the potentially contaminated areas and provide basic demographic information for the populations potentially exposed to mercury. The information in this section is mostly concerned with factors which may affect the human health risks associated with mercury contamination in the Carson drainage and Washoe Valley.

For the areas of potential concern listed in Section 4.5, this section generally describes the geological, hydrological and vegetation characteristics for these areas as well as the land use. The purpose for characterizing land use in the HHRA is to select the land use scenarios and populations of potential concern for characterizing and evaluating exposure to mercury. Land use is also considered in the evaluation of risk reduction versus the cost of remediation. Presented in Figures 5 and 6 is a general description of land use for the study area. For the sake of estimating human exposure, the description of land use is limited to three general descriptions: residential, occupational and recreational land use. The definitions for these terms are as follows:

residential land use refers to areas where the primary land use includes low, medium or high density residential development (single and multi-family dwellings) of a permanent nature.

occupational land use refers to areas where the primary land use includes commercial, processing, manufacturing, packaging, storage and/or distribution of goods and commodities but does not include residential land use. For this HHRA, agricultural land use is also recognized as an occupational land use.

recreational land use refers to "open spaces" where the primary land use includes recreation activities (i.e., fishing, hunting, swimming, riding motorcycles, etc.,). Other uses for open spaces may include protection of environmentally sensitive areas including drainage areas and wetlands.

Given the widespread distribution of mercury in the Carson Drainage and in Washoe Valley as well as the interstate commerce of fish harvested from Lahontan Reservoir, the total population potentially exposed to mercury related to the Comstock Lode is very large. However, in order for a person to receive a dose of mercury which may cause adverse health effects, exposure must be relatively frequent (i.e., constant diet of contaminated fish and/or waterfowl). Therefore, this risk assessment focuses on people who are in the proximity of the areas of potential concern described in Section 4.0. The populations of potential concern which are assessed in this report are listed in Table 5.1.

Discussion regarding the areas of potential concern and the populations of potential concern is broken out and presented herein according to the county encompassing the area and populations of potential concern. Table 5.2 describes which county or counties encompass the different areas of potential concern.

TABLE 5.1: POPULATIONS OF POTENTIAL CONCERN			
COUNTY	**POPULATION OF POTENTIAL CONCERN**	**POPULATION[1]**	**RATIONALE FOR SELECTION**
Lyon	Dayton	3375	Proximity to site[2]
	Silver Springs	3040	Proximity to site
	Silver City	1130	Proximity to site
Storey	Virginia City/Gold Hill	899	Proximity to site
	Mark Twain	435	Proximity to site
Churchill	Fallon	6438	Proximity to site
	Fallon Paiute-Shoshone Reservation	884	Proximity to site
Washoe	New Washoe City	2875	Proximity to site

1. According to 1990 U.S. Census data.
2. "Site" refers to an area or areas of potential concern.

TABLE 5.2: GENERAL LOCATION OF THE AREAS OF POTENTIAL CONCERN				
AREA OF POTENTIAL CONCERN	County			
	Lyon	Storey	Churchill	Washoe
Millsites	X	X		X
Tributaries	X	X		X
Alluvial Fan	X			
Floodplain	X		X	
Carson River	X		X	
Lahontan Reservoir	X		X	
Carson Lake			X	
Stillwater			X	
Indian Lakes			X	
Washoe Lake				X

5.1 LYON COUNTY

5.1.1 CHARACTERIZATION OF THE AREAS OF POTENTIAL CONCERN

General Description

Lyon County is located near the western border of Nevada (see Figure 1) and encompasses 2,024 square miles (1,295,360 acres). The county is composed of north-south mountain ranges with three major valleys: the Carson Plains, Dayton Valley and Churchill Valley. The county is intersected by the Carson River as well as the West Walker River and East Walker River which converge at the southern end of the Mason Valley to become the Walker River. The elevation varies from 4,050 feet east of Fernley to 8,763 feet at Lyon Peak. The major population centers in the county are Fernley, Dayton, Silver Springs, and Yerington. In addition, other population areas include Mound House, Silver City, Stagecoach, Weed Heights, Mason Valley, and Smith Valley.

The populations of potential concern in Lyon County are Dayton, Silver Springs, and Silver City (see Figure 1). The areas of potential concern in Lyon County include millsites, tributaries (Gold Canyon), the alluvial fan below Sixmile Canyon, the Carson River flood plain, Carson River, and Lahontan Reservoir.

Climate

The average total annual precipitation in Lyon County is about 8 inches. Of the total annual precipitation, 40 percent usually falls during April through September, which includes the growing season for most crops. Thunderstorms occur on about 13 days each year, of which 9 occur in summer (USDA Soil Survey (a)). Average annual temperatures range from thirty six (36) to sixty nine (69) degrees Fahrenheit. January temperatures range from fifteen (15) degrees to forty six (46) degrees Fahrenheit. In July, the temperatures range from fifty (50) degrees to ninety two (92) degrees Fahrenheit. The frost-free season ranges between 100 and 120 days (SCS Soil Survey, 1984).

Geology

Lyon county is mostly comprised of the Dayton Valley and Churchill Valley hydrographic areas (Figure 2). The Dayton Valley hydrographic area consists of several basins or areas that extend from the east side of Eagle Valley to the west side of Churchill Valley. Dayton Valley consists of the flood plain of the Carson River immediately east of Eagle Valley, the Mound House area between Carson City and Dayton, the Carson plains, and Stagecoach Valley (Welch et. al., 1989). Churchill Valley is a northeast-trending valley bounded to the north by the eastern end of the Virginia Range, to the east by the Dead Camel Mountains, to the south by Desert Mountains, to the southwest by the Pine Nut Mountains, and to the west by Churchill Butte. The Carson River enters the west side of the valley near Churchill Butte. Prior to the construction of Lahontan Dam, the river left the valley through a canyon which passed through the Dead Camel Mountains. Lahonton Reservoir occupies an irregularly shaped area in the northeast part of the valley (Welch et. al., 1989).

Both valleys consist of a structural basin that formed as a result of extensional faulting. These basins are bounded laterally by consolidated rocks that comprise the mountain block; the basin-fill deposits are underlain by consolidated rocks of the down-faulted valley block. The valleys contain several thousand feet of unconsolidated basin-fill deposits which provide the primary aquifer material in the basins. The basin-fill deposits consist of three units: Tertiary sedimentary rocks; deposits associated with alluvial fans, pediments, and valley lowlands; and deposits associated with Pleistocene Lake Lahontan, ancient Carson River deltas, and river flood plains (Welch et. al., 1989).

Soil

The soils associated with Gold Canyon are generally described as *Lapon-Olac-Wile and Ister-Hyloc-Cagle* (SCS Soil Survey, 1984). *Lapon-Olac-Wile* soils are generally characterized as moderately sloping to very steep, shallow, well drained soils which generally occur on hills and low mountains. *Lapon-Olac-Wile* soils have a dominantly stony, medium textured surface layer and a very gravelly, moderately fine textured subsoil over a hardpan and/or bedrock . *Ister-Hyloc-Cagle* soils are generally characterized as steep, shallow to moderately deep, well drained soils which occur on mountainsides. These soils dominantly have a very coarse to extremely stony surface layer and a fine textured subsoil over weathered bedrock.

The soils associated with the alluvial fan are also generally described as *Lapon-Olac-Wile* and *Saralegui-Wedertz-Vellington* (SCS Soil Survey, 1984). *Saralegui-Wedertz-Vellington* soils are generally characterized as nearly level to strongly sloping, shallow to very deep, well drained soils which generally occur on alluvial fans and lake terraces. These soils have dominantly coarse textured surface layer and a moderately coarse to fine textured subsoil over a hardpan.

The soils surrounding Lahontan Reservoir are generally described as *Patna-Hough-Rusty* and *Lahontan-Orizaba-Wabuska* (SCS Soil Survey, 1984). *Patna-Hough-Rusty* soils are generally characterized as nearly level to moderately steep, very deep, well drained to excessively drained soils which generally occur on dunes, high lake terraces, and lake plains. These soils have a dominantly coarse textured surface layer, moderately coarse textured subsoil, and a coarse textured substratum. They generally occur in areas subject to eolian deposition. *Lahontan-Orizaba-Wabuska* are generally characterized as nearly level, very deep, somewhat poorly drained soils which occur on lake plains and alluvial flats. These soils dominantly are stratified and medium to fine textured throughout the profile.

The soils associated with the Carson River floodplain are generally described as *Dithod-East Fork-Fallon* and *Saralegui-Wedertz-Vellington* (already described) (SCS Soil Survey, 1984). *Dithod-East Fork-Fallon* soils are generally characterized as nearly level, very deep, somewhat poorly drained soils which occur on alluvial flats, flood plains, and low stream terraces. These soils dominantly are stratified and moderately fine textured to coarse textured throughout the profile.

Surface Water

The portion of Lyon County affected by mercury is drained by the Carson River. Runoff from the east-facing slopes of the Sierra Nevada Mountains flows into the Carson River. The river flows east and north through Carson Valley and then turns east again near Carson City to flow through Dayton and the northern part of Lyon County and on to Lahontan Reservoir. The Carson River terminates in the Carson Sink (SCS Soil Survey, 1984). Surface water from the Carson River is only used for irrigation and recreational purposes.

Ground Water

Ground water tapped by wells in the Dayton Valley and Churchill Valley hydrographic areas is present primarily in unconfined aquifers of basin-fill deposits. Locally, where clay or other fine-grained materials occur, the aquifer may be confined. Recharge to the aquifers is by percolation of precipitation from the surrounding mountains, by leakage from the Carson River, and by subsurface inflow from adjacent hydrographic areas (Schaefer and Witney, 1992). Potential recharge from precipitation is approximately 7,900 acre-ft/year. Average annual streamflow into Dayton Valley from Carson Valley and Eagle Valley is approximately 276,000 acre-ft/year and streamflow into Churchill Valley from Dayton Valley was estimated to be 268,000 acre-ft/year (Glancy and Katzer, 1976). The net loss which includes recharge to aquifers near the river in Dayton Valley, along with use of surface water by irrigation, public supply, and evapotranspiration is approximately 8,000 acre-ft/year (Schaefer and Whitney, 1992). The net loss for Churchill Valley is overwhelmingly dominated by evaporation from Lahontan Reservoir and evapotranspiration from vegetation (Schaefer and Whitney, 1992).

Groundwater flow within Dayton Valley and Churchill Valley is generally from west to east, following the course of the Carson River. The average depth to ground water in Dayton Valley is approximately 60 feet. The average depth to ground water in Churchill Valley averages about 40 feet. Domestic water use in Dayton Valley is estimated at approximately 1,100 acre-ft/yr (Schaefer and Whitney, 1992). Domestic water use in Churchill Valley is estimated to have been about 640 acre-ft/year in 1988 (Schaefer and Whitney, 1992). Irrigation is the major use of ground water in the two basins (Schaefer and Whitney, 1992).

Vegetation

In general terms, the vegetation within the county is mainly restricted to three communities, the Pinyon-Juniper, the Big Sagebrush-Grass, and the Low Sagebrush-Grass. The *Lapon-Olac-Wile* and *Ister-Hyloc-Cagle* soils associated with Gold Canyon support big and low sagebrush, Thurber needlegrass, desert needlegrass, pinyon, and juniper. The *Lapon-Olac-Wile* and the *Saralegui-Wedertz-Vellington* soils associated with the alluvial fan support sagebrush, needle grass, and black greasewood. The *Patna-Hough-Rusty* and *Lahontan-Orizaba-Wabuska* soils support sparse stands of black greasewood, and inland saltgrass. The *Dithod-East Fork-Fallon* and *Saralegui-Wedertz-Vellington* soils associated with the Carson River flood plain support western wheatgrass, and big sagebrush in areas not affected by salt and alkali and inland saltgrass and black greasewood in areas affected by salt and alkali (SCS Soil Survey, 1984).

Current Land Use

A general description of current land use is provided in Figure 6. Based on the information provided in Figure 6 and the land use maps provided in the Lyon County Master Plan, the current land use for the areas of potential concern is described in Table 5.3. The historic millsites which are located in Dayton and Silver City are in areas currenly zoned for residential land use. With exception for the Ophir and Morgan mills which are located on land currently used for agriculture/commercial land use, the historic mills adjacent to the Carson River between New Empire and Dayton are in areas which are not currently zoned. Therefore, the land use is described as recreational land. The historic millsites located in Gold Canyon are also in areas which are not currently zoned. However, given that there are active mining operations in Gold Canyon, these areas are described as commercial and recreational land use. According to the Lyon County Master Plan, the alluvial fan area is currently zoned for residential and commercial land use. The flood plain of the Carson River between Dayton and Lahontan Reservoir is currently zoned for residential and agricultural land use. Lahonton Reservoir is mostly limited to recreational land use with exception for the west end of the reservoir which is zoned for residential land use (Silver Springs).

TABLE 5.3: Current Land Use for Areas of Potential Concern in Lyon County			
Area of Potential Concern	**Current Land Use**		
	Residential	**Commercial/ Agricultural**	**Recreational**
Millsites/Dayton & Silver City	X	X	X
Millsites/Carson River		X	X
Millsites/Gold Canyon		X	X
Alluvial Fan	X	X	
Flood Plain	X	X	X
Lahontan Reservoir			X

5.1.2 CHARACTERIZATION OF THE POTENTIALLY EXPOSED POPULATIONS

Demographics

Lyon County's population is concentrated in several population centers and scattered along arterial roadways. According to the 1990 census taken by the Department of Commerce, U.S. Bureau of the Census, the population of Lyon County is 20,001. The population distribution in Lyon County is described in Figure 8. The racial makeup for Lyon County is included in Table 5.4 and the age distribution is included in Table 5.5.

The populations in Lyon County which are potentially exposed to mercury due to their proximity to areas of potential concern as well as land use are Dayton, Silver Springs, Silver City, and Mound House. The population of these communities is described in Table 5.1 and the projected growth rate for the county is described in Table 5.6.

TABLE 5.4: RACIAL MAKEUP FOR COUNTIES INTERSECTED BY CRMS STUDY AREA[1]					
COUNTY/CITY	SELECTED RACIAL GROUP (PERCENT)				
	White	Black	Native American	Asian & Pacific Islander	Hispanic
Lyon	91.9	0.3	3.1	3.8	0.3
Storey	94.6	0.3	2.0	3.1	0.1
Churchill	89.4	1.1	5.0	2.6	0.1
New Washoe City[2]	96.6	0.4	1.5	0.9	2.8

1. State of Nevada Department of Administration, Nevada Statistical Abstract, September 1990.
2. 1990 New Washoe City CDP, Nevada

TABLE 5.5: AGE DISTRIBUTION FOR COUNTIES INTERSECTED BY CRMS STUDY AREA[1]						
COUNTY/CITY	SELECTED AGE GROUP (YEARS)					
	Under 1	1 - 14	15 - 64	65 and Over	75 and Over	Total Population
Lyon	346	3917	12310	3063	1193	19636
Storey	40	341	1444	227	62	2052
Churchill	300	3298	10440	3057	1423	17095
New Washoe City[2]	< 196	< 792	< 1873	210	44	2875

1. Nevada Department of Human Resources, Division of Health Resources and Cost Review, 1987 Staff Memorandum, Population Estimates.
2. 1990 New Washoe City CDP, Nevada

TABLE 5.6: PROJECTED GROWTH RATES FOR COUNTIES INTERSECTED BY THE CRMS STUDY AREA[1]						
COUNTY/CITY	YEAR					
	1980	1990	1995	2000	2005	2010
Lyon	19750	21580		29000		38970
Storey	1503	2526	3560			
Churchill	13917	20521	24372	28947	34380	40832
New Washoe City		2875				

1. U.S Bureau of Census, Census of Population - Nevada State Demographer

Subpopulations of Concern

Populations with potentially high exposure to mercury from other sources may qualify as subpopulations of greater concern. Other types of mercury exposure may include increased exposure in children of workers who are exposed as a result of their occupation. The highest exposure is for children whose parents work in facilities which use mercury but do not use protective clothing. Therefore, mercury is transferred to the home with the clothing (Hudson et. al., 1987). Exposure to mercury also occurs through dental amalgams. Patterson et. al., (1985) detected increased breath levels of mercury in 167 persons with dental restoration with amalgam. Persons using skin lightening creams and soaps containing mercury are also exposed to higher levels than the general population (Barr et. al., 1973). Moreover, prenatal and early postnatal exposure of infants to mercury from maternal use of these products is a source of concern (Lauwerys et. al., 1987). The use of other products that contain mercury such as laxatives and antimicrobial agents can lead to increased exposure as well. Lastly, increased exposure to mercury has been reported from accidental causes, such as broken thermometers (Anger and Jans, 1978) and the misuse of mercury as a cleaning agent (Jaffe et. al., 1983).

5.2 STOREY COUNTY

5.2.1 CHARACTERIZATION OF THE AREAS OF POTENTIAL CONCERN

General Description

Storey County is located in western Nevada and is bordered on the west and north by Washoe County and on the east and south by Lyon County (see Figure 1). The total area of the county is approximately 264 square miles or 167,680 acres. Of the total area of the county, one-sixth lies within the Carson Basin, and five-sixth lies within the Truckee Basin. This equates to approximately 39,146 acres in the Carson Basin and 128,534 acres in the Truckee Basin. Only the area of the county which lies within the Carson Basin is potentially affected by mercury released during the Comstock Lode. The population centers in Storey County are Virginia City/Gold Hill, Virginia Highlands, Mark Twain, and the Truckee River district.

The populations of potential concern in Storey County are Virginia City/Gold Hill and Mark Twain (Table 5.1). The areas of potential concern in Storey county include millsites and the tributaries (Table 5.2).

Climate

Virginia City, the county seat for Storey County, is located on the eastern slope of Mt. Davidson between the Virginia Range and Orleans Hill. At an elevation of over 6000 feet it is considerably higher than most other populated areas in the county, the only exception being the Virginia Highlands area which lies about 5 miles to the northwest. Due to this relatively high elevation, temperature extremes in Virginia City and Virginia Highlands do not vary as greatly as areas of the county in Dayton Valley. The temperature range for Virginia City averages about 22 degrees Fahrenheit. Average temperatures during the summer range from 70 to 85 degrees Fahrenheit and from 40 to 50 degrees Fahrenheit during the winter. The county's high mountainous location is also conducive to higher precipitation which average slightly over 12 inches a year. Average annual precipitation at Virginia City, measured in the rain shadow of Mt. Davidson, amounts to 9.94 inches per year. Lower elevations receive about 5 inches of precipitation per year. Much of this precipitation comes in as snow during the winter (SCS Soil Survey, 1990).

Geology

Much of the county is underlain by relatively stable volcanic bedrock, blanketed by a very shallow surface cover. However, deposits of unstable conglomerates, sandstones, shales and diatomaceous sediments also exist. Gravel and sand deposits also occur which are mostly unsuitable for septic tank usage. The county is also laced with much fault activity. The outstanding geological feature is the world renowned Comstock Lode. This vein of unparalled gold and silver value crops out to the surface along the eastern face of Mount Davidson about 1,200 feet below the summit near the western limit of Virginia City (SCS Soil Survey, 1990).

Soil

The areas of potential concern in Storey County include historic millsites in Virginia City, Gold Hill, Six Mile Canyon, and Seven Mile Canyon. The majority of the soil in and around these areas is generally described as *Aridic Argixerolls-Lithic Xerollic Haplargids* (SCS Soil Survey, 1990). *Aridic Argixerolls-Lithic Xerollic Haplargids* soil are generally characterized as moderately steep to very steep, shallow to deep, well drained soils; on high mountains. These soils have a gravelly to extremely stony, medium textured and moderately coarse textured upper layer and a medium textured to moderately fine textured lower layer. The soil in the bottom half of Sixmile Canyon is generally described as *Lithic*

Xerollic Haplargids-Xerollic Haplargids-Entic Chromoxererts (SCS Soil Survey, 1990). These soils are generally characterized as moderately sloping to very steep, shallow to deep, well drained soils; on mountains, foothill, and mountain valley fans and in basins. These soils have a gravelly to extremely stony, medium textured upper layer and moderately fine textured, gravelly or coarse lower layer over hard bedrock. Bedrock is at a depth of 20 inches or more.

The majority of the soils in Storey County exhibit a moderate erosion hazard with some areas characterized as severe. Any disturbance to natural conditions (i.e., disturbance of vegetation) will greatly increase the erosion potential. Soils are also easily eroded by wind (Storey County, 1991). According to the SCS soil classification system, the soils in the area of concern have low irrigation capability.

Surface Water

As a result of the rain shadow created by the Sierra Nevada Mountains and the Virginia Range, annual precipitation for Storey County is low. Average annual precipitation at Virginia City, measured in the rain shadow of Mt. Davidson amounts to 9.94 inches per year. At elevations above the Mt. Davidson rain shadow, annual precipitation ranges between 12 and 15 inches per year and at lower elevations, annual precipitation is approximately 5 inches per year. The county has negligible areas of snow accumulation. Lake areas are limited to a sum of ten acres, a figure which includes water supply reservoirs. The length of rivers and streams is approximately fourteen miles, including the Truckee River which borders the County on the north. The evaporation rate in the County is approximately 50 inches per year. Due to the high evaporation, and phreatophyte consumption, recharge is limited to approximately 5% of the total precipitation.

Ground Water

With exception for the alluvial fans which form a perimeter around the Virginia Range, ground water is not a viable water source in Storey County. Ground water is generally not potable in the county due to low precipitation, low recharge, and the soil mantle is high in sulfates, iron, and numerous other chemical elements which concentrate in the aquifers. Due to the low quality of ground water in Storey County, the only source of domestic water for the Virginia City-Gold Hill area comes from the State owned Marlette-Hobart system. Groundwater wells of adequate quality have been developed along the flood plain of the Truckee River and also within the Mark Twain area which lies within a declared critical ground water basin (Storey County, 1991).

Vegetation

Vegetation within the county is mainly restricted to three communities, the Pinyon-Juniper, the Big Sagebrush-Grass, and the Low Sagebrush-Grass (SCS Soil Survey, 1990). The Pinyon-Juniper, located in the upper elevations of Storey County, is accompanied with an understory of big sagebrush and the antelope bitterbrush. Frequently lying above the Pinyon-Juniper is the Low Sagebrush-Grass community. Associated with low sage are grasses and forbs such as needlegrass and balsamroot. Below the Pinyon-Juniper lie the Big Sagebrush-Grass community. Big sagebrush is accompanied by a host of grasses, forbs and shrubs. These vegetation communities are typical of a harsh climate and recovery from disturbance is slow.

Current and Future Land Use

Current land use for Storey County is generally described in Figure 6. The current and projected land use for the historic millsites located in Virginia City and Gold Hill are generally residential land use. Current land use in the areas of potential concern in Six Mile and Seven Mile Canyon does not include residential land use and it is undetermined if future land use will include residential land use. With exception for the American Eagle Resources heap leaching operation located in Six Mile Canyon, the area is presently not zoned for any particular land use. Therefore, the current land use is described as occupational and recreational land use.

5.2.2 CHARACTERIZATION OF POTENTIALLY EXPOSED POPULATION

Demographics

Storey County's population is concentrated in Virginia City/Gold Hill, Virginia Highlands and the River District which refers to the population in and around Lockwood adjacent to the Truckee River. In 1990, the U.S. Bureau of the Census counted 2,526 individuals in Storey County. The population distribution in Storey County is described in Figure 8. The racial makeup for Storey County is described in Table 5.4, the age distribution is described in Table 5.5, and the projected growth rate is described in Table 5.6.

The populations in Storey County which are potentially exposed to mercury due to their proximity to source areas or areas of accumulation are Virginia City/Gold Hill and Mark Twain. The population of Virginia City/Gold Hill and Mark Twain are described in Table 5.1.

Subpopulations of Concern

Subpopulations with potentially higher exposure to mercury include people who eat fish and/or waterfowl from the Carson River system or children who frequently play in areas where high levels of mercury occur. Subpopulations of greater concern may also include people who are chronically exposed to mercury by some other means which are discussed in Section 5.2.2.

5.3 CHURCHILL COUNTY

5.3.1 CHARACTERIZATION OF AREAS OF POTENTIAL CONCERN

Location

Churchill County is the largest county intersected by the CRMS. Churchill County consists of approximately 4,911 square miles (3,144,320 acres) and is located in west-central Nevada, east of Lyon and Washoe County, south of Pershing County, and North of Mineral County (see Figure 1). Most of the county is below 4,000 feet. The highest area of interior lowlands is an old delta that borders the area near Lahontan Dam, at an altitude of 4,100 feet. The lowest parts of the area are Carson Sink, a playa in the northern part of the county at an altitude of 3,860 to 3,880 feet; Carson Lake, a shallow lake in the southern part of the county is at an altitude of 3,908 feet; and the Stillwater Lake, a chain of small lakes, ponds, and marshes that extend 20 miles southwestward from Carson Sink is at an altitude of 3,870 to 3,880 feet (SCS Soil Survey, 1975).

The major population centers in Churchill County are Fallon, Fallon Paiute-Shoshone Reservation ("Fallon Reservation"), and the Fallon Naval Air Station. The populations of potential concern are residents of Fallon and the Fallon Reservation that live on or adjacent to the current or historic flood plain of the Carson River and residents who consume fish and/or waterfowl from the Carson River System. The areas of potential concern in Churchill County include the current and historic flood plain of the Carson River below Lahontan Dam, Lahontan Reservoir, Carson Lake, Stillwater Wildlife Refuge (including all of teh lakes within the designated refuge area), and Indian Lakes.

Climate

The climate of Churchill County is greatly affected by the rain shadow effect created by the Sierra Nevada Mountain Range. The climate is characterized as arid, continental type with precipitation averaging slightly more than 5 inches annually. In addition to the rain shadow effect, the climate of Churchill county is affected by the flow of warm, moist air from the south. This is the main source of summer thunderstorms that occur 10 to 15 days a year. Snow falls each year, but is generally very light and melts within a few days. Windspeed in the region averages less than 7 miles per hour, and the prevailing wind is from south to north in a clockwise direction. The strongest wind recorded in Fallon was approximately 55 miles per hour (SCS Soil Survey, 1975).

Geology

Churchill County includes the Churchill Valley and Carson Desert hydrographic areas (Figure 2). Churchill Valley is described in Section 5.2.1. Carson Desert is the largest valley in the Carson River basin with a maximum length of 70 miles and a maximum width of 25 miles. Basin fill of the Carson Desert consists of lacustrine, fluvial, subaerial, eolian, and volcanisclastic sediments and interbedded volcanic rocks (Olmsted, 1985).

Soil

The soils associated with current and historic flood plain of the Carson River are generally described as *Dia-Sagouspe-East Fork* association. This association occupies low stream terraces and flood plains, are nearly level, and somewhat poorly drained. The *Dia* soils are very deep and are silty clay loam or clay loam. *Sagouspe* soils are very deep and generally occur on smooth stream terraces. They are dominantly loamy sand and have thin strata of sandy to silty clay loam. *East Fork* soils are very deep and are on smooth flood plains and low stream terraces. They have clay loam or silty loam texture throughout (SCS Soil Survey, 1975).

The soils associated with Carson Lake and Stillwater are generally described as *Carson-Stillwater* association, *Lahontan* association, and *Playas-Parran* association. *Carson-Stillwater* association are nearly level, poorly drained, fine textured soils which generally occur on flood plains. *Carson* soils are very deep and have a clay texture throughout. *Stillwater* soils are very deep and have a texture of stratified clay loam and silty clay loam. *Lahontan* association are nearly level, somewhat poorly drained, fine-textured soils that generally occur on deltaic flood plains and in basins. *Lahontan* soils are strongly alkaline and have a clay or silty clay texture throughout. *Playas-Parran* association are nearly level playas and somewhat poorly drained, fine-textured soils that generally occur in basins and on low lake terraces. *Playas* soils are very deep, intermittently ponded, and strongly alkaline to very strongly alkaline. *Parran* soils are very deep, somewhat poorly drained, strongly saline silty clay (SCS

Soil Survey, 1975).

The soils associated with Indian Lakes are generally described as *Tipperary-Appian* association. This association is described as nearly level to strongly sloping, well-drained, coarse textured and moderately coarse textured soils which generally occur on lake terraces and sand dunes (SCS Soil Survey, 1975).

Surface Water

With exception for the northern end of Lahontan Reservoir, the surface water in Churchill County is in the Carson Desert hydrographic area (Figure 2). The Carson Desert hydrographic area is the terminal sink of the Carson River which enters the basin just below Lahontan Dam. Average flow of the river below the dam, including Truckee River water diverted to Lahontan Reservoir by way of the Truckee Canal, was 380,000 acre-ft/yr for the period 1919-69 (Glancy and Katzer, 1976). Most of the Carson River flow is diverted for irrigation in the Truckee Carson Irrigation District (TCID). Flow which is not diverted for irrigation flows into Carson Lake. Water flows from Carson Lake through the Stillwater Slough to the Stillwater Wildlife Management Area (SWMA). Outflows from SWMA, if any, discharge to the Carson Sink, which during abnormally high flow years may receive overflows from the Humboldt River (Hoffman et. al., 1990). The acreage of wetlands associated with Carson Lake and the SWMA is approximately 5,600 acres and 9,600 acres, respectively (Hoffman et. al., 1990). The quantity of streamflow to Carson Lake and the SWMA is not well monitored. During nonspill years, the quantity of surface water that flows to the wetlands has been estimated to be about 25% of the Lahontan Reservoir releases minus approximately 35,000 acre-ft which is loss to evapotranspiration and seepage to the shallow alluvial aquifer (U.S. Bureau of Reclamation, 1987).

Ground Water

Glancy (1986) categorized the Fallon area valley-fill aquifers into four general hydrologic systems: "(1) a shallow alluvial aquifer system extending from near land surface to a depth of about 50 ft; (2) an intermediate-depth alluvial aquifer system underlying the shallow system and extending from about 50 ft to depths that may be as great as 500 to 1,000 ft in some areas; (3) a basalt-aquifer system that is as shallow as 200 ft but may be as deep as 1,000 ft in places; and (4) a deep alluvial aquifer system underlying the intermediate alluvial and basalt systems, generally below depths of 500 to 1,000 ft."

As a consequence of extensive irrigation in the Carson Desert, the shallow ground water in the

Fallon agricultural area has risen approximately 60 feet. The rise in the water table, attributed to seepage from the canals, laterals, and irrigated fields, occurred from about 1906 to 1930 . Drains were dug to provide adequate drainage of the soil profile to support the permanent irrigated agriculture. The shallow alluvial aquifer which is recharged with irrigation drainage is used as a domestic drinking-water source for much of rural Fallon. The City of Fallon and the Fallon Naval Air Station obtain their drinking water from a localized deeper basalt-aquifer system as opposed to the shallow aquifer.

Vegetation

The *Carson-Stillwater* association soils which are found around the Carson Lake area and SWMA are generally covered with black greasewood, suaeda, saltbush, and saltgrass. The *Dia-Sagouspe-East Fork* association which in the central farming area surrounding Fallon are generally covered with big sagebrush and meadow grass in the salt- and alkali-free areas and black greasewood and saltgrass in the salt and alkali affected areas. The *Playas-Parran* association soils which are found in broad basins and low-lying lake terraces and are generally covered with a very sparse stand of black greasewood, shadscale, suaeda, and iodine bush (SCS Soil Survy, 1975). Of the approximately 62,000 acres under irrigation in the TCID, about 33,000 acres is used for alfalfa, about 7,000 acres is used for grain, 2,000 acres is used for corn, and 20,000 acres is used to maintain pastures for cattle.

Current and Future Land Use

The current land use for the areas of potential concern is generally described in Figure 5. Based on the information provided in Figure 5 and the Churchill County Master Plan, Table 5.7 describes the current land use for the areas of potential concern. The current land use for the flood plain area associated with the South Branch of the Carson River, the main channel of the Carson River before the construction of Lahontan Dam, is mostly agricultural with low density residential areas. The current land use for the flood plain associated with the current channel of the Carson River is also agricultural and residential. The portion of Lahontan Reservoir included in Churchill County as well as Stillwater and Indian Lakes are not zoned for either agricultural or residential land use. Therefore, these areas are described as recreational land use. According to the Churchill County Master Plan and Figure 5, the Carson Lake area is described as agricultural land use as well as recreational land use.

TABLE 5.7: Current Land Use for Areas of Potential Concern in Churchill County			
Area of Potential Concern	**Current Land Use**		
	Residential	**Commercial/ Agricultural**	**Recreational**
Carson River Flood Plain	X	X	X
Lahontan Reservoir			X
Carson Lake		X	X
Stillwater			X
Indian Lakes			X

5.3.2 CHARACTERIZATION OF POTENTIALLY EXPOSED POPULATION

Demographics

Churchill County's population is mostly concentrated in Fallon and the surrounding area. According to the 1990 census taken by the Department of Commerce, U.S. Bureau of the Census, the population of Churchill County is 17,938 and the population of Fallon is 6,438. The population distribution in Churchill County is described in Figure 7. The racial makeup and the age distribution for Churchill County are described in Table 5.4 and Table 5.5, respectively. The projected growth rate for Churchill County is described in Figure 5.6.

The populations in Churchill County which are potentially exposed to mercury due to their proximity to areas of potential concern are residents of the Fallon area who live near or on the modern or historic flood plain of the Carson River. The populations of potential concern due to land use include residents of the Fallon area or the Paiute Reservation which eat fish and/or waterfowl from the Carson River, Lahontan Reservoir and/or the terminal wetlands. Also of potential concern are Native Americans who consume bullrush roots ("tules") from Carson Lake or SWMA.

Subpopulations of Concern

Subpopulations with potentially higher exposure to mercury are discussed in Section 5.2.2.

5.4 WASHOE COUNTY

5.4.1 CHARACTERIZATION OF THE AREAS OF POTENTIAL CONCERN

Location

The portion of Washoe County which is intersected by the CRMS is described as the "South Valley (Washoe, 1992)." The South Valley is located in the southern portion of Washoe County and covers approximately 82 square miles. The South Valley is approximately ten miles in length and eight miles in width, and encompasses Steamboat, Pleasant, and Washoe Valleys. The area is generally bounded on the north by the Truckee Meadows, on the east by the Storey County line, on the south by the Carson City line, and on the west by the Forest planning area (see Figure 1).

Climate

The climate of the South Valley is much like the climate of Eagle Valley in the Carson River basin. The climate is dominated by the Sierra Nevada mountain range which receives as much as 25 to 50 inches/year of precipitation at higher altitudes. However, areas to the east such as the South Valley are dry because much of the moisture carried by winter storms from the Pacific Ocean falls as snow or rain in the mountains (the rainshadow effect). The climate of the South Valley is fairly mild except for areas of high altitude. The air temperatures of the South Valley are fairly mild with mean temperatures during January ranging between 30 and 40 degrees Fahrenheit (Washoe, 1992).

Geology

The South Valley consists of three relatively flat valleys bounded by the lower slopes of the Carson Range to the west and the Virginia Range to the east. Washoe, Pleasant and Steamboat Valleys are separated by hills extending east and west from the mountains to the valley floors. The valley floors have elevations ranging from 4,600 feet in Steamboat Valley to over 5,000 feet in Washoe Valley.

Soil

The areas of concern include any historic millsites located in Washoe Valley and the sediment in Washoe and Little Washoe Lake. According to Ansari (1989), there were several mills located in New

Washoe City and in Franktown. Although mercury contamination in sediment indicates that there were mills which released mercury into this drainage, EPA was unable to identify millsites in Washoe Valley or Pleasant Valley. Thus, soil information is only presented for the perimeter areas of Washoe and Little Washoe Lake.

Soils in the bottom of Washoe Valley are alluvial deposits generally described as *Jubilee-Bishop* soils (SCS Soil Survey, 1983). These soils are described as nearly level and gently sloping soils which are moderately to poorly drained. The surface layers consist of sandy loam and loam with a thickness of 20 to 28 inches. Below the surface layer to depth of approximately 60 inches the soils are stratified coarse and sandy clay loam.

Surface Water Hydrology

The South Valley lies entirely within the drainage basin of Steamboat Creek with Washoe and Little Washoe Lakes as the most prominent water features in the valley. The lakes are recharged primarily by runoff from the eastern slope of the Carson Range. Franktown and Ophir Creeks provide the bulk of the surface runoff that reaches the valley floor. Steamboat Creek, flowing from Washoe Valley, and Brown's Creek and Galena Creek draining from the Carson Range, comprise the bulk of the surface water resources for Pleasant Valley. Steamboat Valley does not receive any direct runoff from the Carson Range. As a result, no natural perennial streams other than Steamboat Creek flow into the valley (Washoe, 1992).

Ground Water Hydrology

Ground water occurs throughout the South Valley. Generally, the best location for ground water occurrence and development is on the valley floors. Most of the domestic and irrigation wells are located in relatively young sediments that fill the basins in the South Valley. Ground water that is high in boron and arsenic is associated with the geothermal discharges at Steamboat Springs. Ground water containing high amounts of nitrate occurs in Steamboat Valley and on the east side of Washoe Valley. High concentrations of fluoride occur in the eastern portion of Washoe Valley (Washoe, 1992).

Vegetation

Vegetation in the South Valley is strongly influenced by the immediate proximity of the Carson Range of the Sierra Nevada Mountains and the associated rain shadow. The major vegetation types are northern desert shrub, chaparral, salt desert shrub, coniferous forest, pinyon-juniper forest, wetlands, riparian woodland, pasture and cultivated fields, and annual grassland. One of the most important vegetation types to wildlife is the riparian woodland found along perennial streams. Similarly, all wetlands found in the South Valley represent a valuable habitat for waterfowl and shorebirds (Washoe, 1992). The native vegetation generally supported by *Jubilee-Bishop* soils is mainly meadow grasses.

Current and Future Land Use

Current land use for Washoe County is generally described in Figure 6. According to the Washoe County Comprehensive Plan, current land use for the perimeter of Washoe and Little Washoe Lake is recreational. Although future land use is not defined, the Washoe County Comprehensive Plan recommends that the wetland and riparian wildlife habitat associated with Washoe and Little Washoe Lake is protected. Current land use for the southern end of Pleasant Valley is residential and recreational.

5.4.2 CHARACTERIZATION OF POTENTIALLY EXPOSED POPULATION

Demographics

The current population of the South Valley is approximately 4,596 and is projected to increase to 9,800 by the year 2007. Residential populations are concentrated in Steamboat Valley, Pleasant Valley and on the east side of Washoe Lake (New Washoe City). The population distribution in the South Valley of Washoe County is described in Figure 8. The racial makeup and the age distribution for New Washoe City are provided in Table 5.4 and Table 5.5.

The populations in the South Valley which are potentially exposed to mercury due to their proximity to areas of potential concern are residents of New Washoe City and the Pleasant Valley area. Any person who uses Washoe or Little Washoe Lake for recreation are also potentially exposed to mercury. The population of New Washoe City is included in Table 5.1 and the projected growth rate for Washoe County is included in Table 5.6.

Subpopulations of Concern

Subpopulations with potentially higher exposure to mercury are discussed in Section 5.2.2.

6.0 SUMMARY OF REMEDIAL INVESTIGATION

Due to the widespread distribution of mercury in the Carson River basin and in Washoe Valley, the objectives of the remedial investigation (RI) did not include delineating the extent of contamination. Rather, the principle objective of this phase of the RI was to characterize and assess the human health risks related to the widespread distribution of mercury. This summary of the RI describes the approach and methods used to collect and evaluate data for the HHRA as well as presents the results of the investigations.

6.1 SAMPLING OBJECTIVES

The sampling strategy for Phase I of the RI was developed to achieve the following objectives:

- identify contaminants of potential concern (COPCs);
- estimate exposure point concentrations for potentially complete exposure pathways associated with current and future land use; and
- characterize surface soil concentrations at and around historic millsites.

6.2 DATA COLLECTION STRATEGY AND METHODS TO EVALUATE DATA

The sampling strategy for Phase I of the RI is described herein according to the specified sampling objectives.

6.2.1 IDENTIFY CONTAMINANTS OF POTENTIAL CONCERN (COPC)

Accomplishing this objective entailed identifying and measuring the species of mercury occurring in soil and determining if any other inorganics readily occur in soil at levels of potential concern. Characterizing the relative concentration of different mercury species occurring in soil is important to the HHRA because different species of mercury demonstrate different fate and transport properties and have different toxicity characteristics which are described in Section 8.0. Determining if other trace metals readily occur in soil at levels of potential concern is important since extraction and processing activities associated with mining can create high concentrations of trace metals in the environment which could pose human health risks.

In order to characterize mercury speciation in soil, 34 surface soil samples were collected from different soil environments where elevated levels of mercury were found to occur. Soil samples were collected from extant tailing piles; from deposits where tailings were blended with the different soil types occurring in Gold Canyon, Sixmile Canyon, the alluvial fan, and on the flood plain; and from areas where there were no ostensible tailings. Other than noting the general physical characteristics of the different soil environments, there was no effort to relate the geochemistry of the soil environment with the relative concentration of different mercury species. Each soil sample was analyzed for elemental mercury, mercuric sulfide, mercuric chloride, and methyl mercury.

All of the soil samples were analyzed by the Oak Ridge Research Institute (ORRI) and 9 duplicate samples were analyzed by EPA's Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV). The results from both of these labs are provided in Tables B.2 and B.3. As the results indicate, there was a significant difference in the results from ORRI and the results from EMSL-LV, particularly for elemental mercury and mercuric sulfide. Although the specific reason(s) for this discrepancy were not determined, EPA used the results from EMSL-LV for this HHRA. The reason is as follows:

- the relative percentage of mercuric chloride ("soluble mercury") is the most important measurement from the speciation data since mercuric chloride is the most bioavailable of the inorganic mercury species, thus the relative concentrations of mercuric chloride in the soil largely determines what level of total mercury is acceptable in soil; and

- the analytical method employed by EMSL-LV directly measures the relative concentration of soluble mercury in the soil sample whereby the ORRI method determines the level of soluble mercury by deduction.

The results from EMSL-LV are summarized in Table 6.1. Both the results from EMSL-LV and the results from ORRI demonstrated that the predominate species of mercury in soil are either mercuric sulfide or elemental mercury which both have relatively low bioavailability. For both data sets, there was no discernable correlation between the relative concentration of different mercury species and the soil environment from where the sample was derived. Additional information regarding the bioavailability of the different mercury species is provided in Section 7 and Appendix G.

To determine if other trace metals readily occur at levels of concern, approximately 10% of the soil samples collected were analyzed for all trace metals included in EPA's Target Analyte List (TAL). Contaminants of potential concern (COPC) were selected by comparing the maximum detected concentration of the trace metals with the respective *preliminary remediation goals (PRGs)*[1] . If the maximum detected level exceeded the PRG, then the average concentration at millsites was compared with the background concentration. If this concentration exceeded background, then the contaminant was identified as a potential concern. Background concentrations were derived from the arithmetic mean of the data developed by Tidball et. al., 1991. The study conducted by Tidball entailed collecting 398 surface soil samples (0 - 12") from locations throughout the Carson basin and measuring the levels of various trace metals. Table 6.2 summarizes the maximum detected concentrations, PRGs, and the estimated background concentrations for selected trace metals. As is described in Table 6.2, mercury, arsenic, beryllium and lead were found to occur at levels exceeding the respective PRG. Beryllium was not identified as a COPC because the average concentration at millsites did not exceed the estimated background concentration. Thus, mercury, arsenic, and lead were identified as contaminants of potential concern.

TABLE 6.1: Mercury Speciation in Soils, Samples Analyzed by EPA EMSL-Las Vegas

Sample ID No.	Sample Date	Total Hg (mg/kg)	Relative Percent		
			Hg (0)	HgS	Soluble Hg
MS 001-SL-41-A[1]	04/28/93	261.00	54	44	2
MS 005-SL-12-A	05/27/93	991.00	71	27	2
MS 012-SL-09-A	06/03/93	669.00	48	51	1
MS 012-SL-38-A	06/03/93	1154.00	8	82	10
MS 017-SL-03-A	06/10/93	3124.00	9	90	0.2
TP 004-SL-07-A[2]	06/17/93	1632.00	13	82	6
TP 007-SL-04-A	06/17/93	1273.00	23	74	3
TP 011-SL-05-A	06/23/93	2385.00	22	77	0.3
TP 011-SL-09-A	06/23/93	1350.00	14	86	1

1. Sample identification prefix for samples collected from historic millsites.
2. Sample identification prefix for samples collected from extant tailing piles.

[1] Preliminary remediation goals (PRGs) are health-based levels determined without site specific information and are mainly used for general screening purposes (EPA, 1993).

TABLE 6.2: Identification of Contaminants of Potential Concern (COPC)								
Trace Metal	Maximum Detected (mg/kg)	Sample Area	PRG (mg/kg)[1]	Exceeds PRG	Background[2] (mg/kg)	Mean Concentration at Millsites (mg/kg)[3]	Exceeds Background	COPC
Antimony	21.80	MS053	31	No				No
Arsenic	627.00	TP017	0.97	Yes	13.14	29.69	Yes	Yes
Barium	534.00	MS060	5500	No				No
Beryllium	1.70	MS019	0.40	Yes	1.55	0.60	No	No
Cadmium	18.20	TP002	39	No				No
Chromium	28.80	TP013	44	No				No
Lead	4790.00	MS060	500	Yes	17.16	129.50	Yes	Yes
Manganese	1690.00	MS055	7800	No				No
Mercury	4672.00	TP007	25	Yes	1.24	350.50	Yes	Yes
Nickel	22.00	TP017	1600	No				No
Selenium	15.00	MS034	390	No				No
Silver	134.00	TP015	390	No				No
Thallium	0.85	TP020	5.5	No				No
Vanadium	83.20	FA012	550	No				No

1. EPA, 1993a
2. Background concentrations are the arithmetic mean of data developed by Tidball et. al., 1991
3. Arithmetic mean for samples from all of the millisites.

Although it appears that the Comstock mills created concentrated levels of arsenic in the environment, Comstock mining activities are not considered important sources of arsenic in the Carson Desert hydrographic area. Arsenic is a naturally occurring trace metal in this region with a background concentration of approximately 13 mg/kg, dry weight (Tidball et. al., 1991). According to surface water and sediment data for the SWMA (Rowe et. al., 1991) and groundwater data from the Carson Desert (Welch et. al., 1989), the highest arsenic levels in the drainage are in the Carson Desert hydrographic area. According to the data developed by Rowe et. al., 1991 for the SWMA, the average concentration of arsenic in sediment is 24.45 mg/kg, dry weight (range = 10 - 37 mg/kg, n = 11) and the average concentration of arsenic in surface water is 133 ug/l (range = 11 - 1300 ug/l and n = 57). Groundwater data developed by Welch et. al., 1989 indicated that arsenic frequently exceeds National Drinking Water Standard (50 ug/l) in shallow and deep aquifers throughout the Carson Desert (107 of 190 samples). Among the hydrographic areas evaluated by Welch et. al., 1989, the Carson Desert had the highest arsenic levels in ground water. Elevated levels of arsenic in ground water in the Carson Desert hydrographic is partly attributed to the presence of sediments deposited during high levels of Pleistocene Lake Lahontan (Welch et. al, 1989). As Lake Lahontan receded, dissolved-solids concentrated and accumulated in the sediments of lowland areas and, in some cases, these sediments became aquifer formations (Welch et. al., 1989). Elevated levels of arsenic in the sediments and surface water of Carson Lake and Stillwater is partly attributed to agricultural irrigation which has been shown to mobilize salts and trace elements such as arsenic (Hoffman et. al., 1990). Coupled with the reduced inflow of fresh water due to irrigation, trace metals such as arsenic are concentrated in the sediments and surface water of the terminal wetlands. Based on this information, it was determined that Comstock activities were not a significant source of arsenic in the Carson Desert hydrographic area.

6.2.2 ESTIMATE EXPOSURE POINT CONCENTRATIONS FOR POTENTIALLY COMPLETE EXPOSURE PATHWAYS

In order to estimate exposure point concentrations for potentially complete exposure pathways, samples were collected from each medium associated with a potentially complete exposure pathway and an exposure point concentration was derived. Exposure point concentrations are derived from the arithmetic mean and the associated 95 percent upper confidence limit (95 UCL). If the data set was insufficient to calculate the 95 UCL, the maximum detected value was used as the exposure point concentration per EPA guidance (EPA, 1989a).

This section describes the sampling strategy used to collect samples and the methods used to derive exposure point concentrations. The sampling strategy was developed based on the sources of mercury, the fate and transport properties of mercury, and the exposure pathways of concern for mercury. Mercury was considered an acceptable indicator contaminant for arsenic and lead because the Comstock mills were point sources for all of these metals, the fate and transport properties of these metals are similar, and the exposure pathways of concern are similar. Since mercury was initially identified as the principal contaminant of concern, only 10 percent of all the samples collected were analyzed for other trace metals, including arsenic and lead. Therefore, the data sets for determining exposure point concentrations for these contaminants were less robust. Methods used to derive exposure point concentrations for lead are not described in this section because EPA evaluates exposure to lead based on estimated blood levels rather than on the estimated level of exposure. Although this approach also requires deriving exposure point concentrations, it also requires a more comprehensive evaluation of lead exposure and a specific model to estimate blood lead levels. Therefore, the exposure assessment and risk characterization for lead are discussed separately in Section 10.

The sampling program was designed to estimate exposure point concentrations for the exposure pathways of potential concern and the areas of potential concern. The exposure pathways of potential concern which were selected in the scoping phase of this investigation are as follows:

- incidental ingestion of soils,
- ingestion of groundwater,
- inhalation of airborne contaminants,
- ingestion of domestic produce and ingestion of bullrush root ("tules"), and
- ingestion of fish and waterfowl.

Section 7.0 identifies all of the potential exposure pathways and explains why certain exposure pathways were screened out of the exposure assessment. The sampling strategies and data evaluation methods are described herein according to these exposure pathways.

<u>Incidental Ingestion of Soil at and around Historic Millsites</u>

Among the areas where mercury was thought to occur in soils, it was assumed that the highest levels of mercury would occur at and around historic millsites and extant tailing piles since there would be minimal dilution caused by transport. Therefore, these areas were the focus of the sampling strategy. The first step of the sampling strategy was to locate and map the locations of the historic Comstock mills. The second step was to select a group of millsites where soil data could be used to approximate exposure point concentrations for residential and recreational land use. The final step was to develop a soil sampling design which would provide a statistically significant data set for deriving exposure point concentrations.

Locating and mapping the historic millsites was conducted by Comstock Services, Piedmont Engineering and Scientific Applications International Corporation (SAIC) for EPA (SAIC, 1994). Out of this research, 113 mills were identified and mapped. Although the actual number of mills having operated during the Comstock era is unknown, it is believed that any mills not identified and located through this exhaustive research effort were not significant operations. Information about each of the mills identified is summarized in Appendix A and the locations of the mills are described in Figure 3.

The area selected for evaluating incidental ingestion of soil associated with residential land use was Dayton and the areas selected for evaluating exposure associated with recreational land use were Sixmile Canyon and Brunswick Canyon. The Dayton residential area was selected for the exposure assessment because the town has a fairly large residential population living over or near historic millsites. Also, because Dayton is on the flood plain of the Carson River and below the mouth of Gold Canyon, tailings from upgradient source areas could be deposited in this area. Sixmile Canyon and Brunswick Canyon were selected for evaluating exposure related to recreational land use because these are open landuse areas where there is evidence of recreational use (i.e., hiking trails and campgrounds).

The sampling areas in Dayton were selected according to the location of the historic mills and any associated features (i.e., tailings ponds, flumes, etc.,). The historic millsites in Dayton included the Birdsall, French's, Kustel and Winters, Rock Point, Freeborn and Sheldon, and Mineral Rapids millsites. The boundaries of the sample areas were defined by the original boundaries of the millsites and any existing boundaries (i.e., river, ditch, roads, etc.,). The sampling areas selected for deriving exposure point concentrations in Dayton were MS001, MS002, MS004, and MS005[1]. These sampling areas are described in Figure 9. The sampling area selected for deriving exposure point concentrations in Brunswick Canyon was MS015 and the sampling area selected for Sixmile Canyon was TP007. The highest levels of mercury in Brunswick- and Sixmile Canyon were detected at these sampling areas. These sampling areas are described in Figure 21 and 22.

The number of surface soil samples (0 - 6") per sampling area in Dayton was determined using the equation for one-sided, one-sample t-test and the performance standards provided in EPA's Guidance for Data Useability in Risk Assessments, Interim Final dated October 1990 (E&E, 1992). Given that mercury levels measured in subsurface soil (6 - 24") would not be used to derive exposure point concentrations, the number of subsurface samples was limited to 1 to 5 samples per area.

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[1] Table B.1 identifies the mills which correspond with the sample area identification numbers.

Surface soil sampling locations were selected with a systematic grid system. Subsurface samples were collected at locations where elevated mercury levels (>25 ppm) were detected in the surface soil. Due to the coarse gravel subsoil and a hardpan, subsurface sampling was generally limited to a depth of 24" with a hand auger. The surface sampling results and subsurface sampling results for these sampling areas are presented in Tables B.4 and B.10, respectively.

The sampling areas in Brunswick Canyon and Sixmile Canyon were not sampled as thoroughly as the areas in Dayton. The strategy used to determine sampling locations and the number of samples for these sample areas is discussed in Section 6.2.3. The surface sampling results and subsurface sampling results for these sampling areas are included in Tables B.4 and B.5, respectively.

In order to calculate exposure point concentrations for mercury, subareas were broken out of the original sampling areas. The subareas were defined in order to screen out non-detect values and thereby select a more robust data set for calculating statistical values (i.e., arithmetic mean and the 95 UCL). The boundaries of the subareas were defined by sample results equal to or greater than 25 mg/kg, the preliminary remediation goal for mercury (Seidel, 1991). The subareas which were defined by this method are shown in Figures 10, 26 and 27. The statistical results for these subareas are included in Table B.13. Exposure point concentrations for Dayton were derived from MS004-SA2. MS015-SA and TP007-SA were selected for Brunswick Canyon and Sixmile Canyon because these sampling areas include the highest levels measured at each of these areas. For each of these subareas, the 95 UCL was used to estimate the maximum ("high-end") exposure and the arithmetic mean was used to estimate the "typical" exposure. These exposure point concentrations are provided in Table 6.4.

Exposure point concentrations for arsenic were derived from the MS002 sample area (see Table B.5). The 95 UCL was used for the high-end exposure estimate and the arithmetic mean was used for the typical exposure estimate. Using all of the data developed for Sixmile Canyon, the 95 UCL and the arithmetic mean were used as exposure points for this area. Exposure points were not derived for Brunswick Canyon. These exposure point concentrations are provided in Table 6.5.

Incidental Ingestion of Soil on the Alluvial Fan the Flood Plain

Most of the mercury that is distributed on the alluvial fan and on the flood plain is associated with mill tailings that were transported by fluvial processes. Thus, deposits of tailings mainly occur in stream channels on the alluvial fan and as overbank deposits and sand bar deposits in the flood plain. In addition to fluvial processes, it is thought that eolian transport mechanisms account for the widespread distribution of mercury at lower levels.

In order to collect samples which represent the levels of mercury occurring on the alluvial fan, surface soil samples were collected along 4 radial transects. Along each transect, samples were collected from the beds of the stream channels and from the areas between the streams. A total of 43 surface samples were collected on the alluvial fan. Due to the coarse subsurface texture of the alluvial fan, subsurface samples were not collected. However, samples were collected from the banks of stream channels which, in some places, were cutting through deposited tailings. Sample locations are indicated in Figure 11.

In order to collect samples which represent the levels of mercury occurring on the flood plain above Lahontan Reservoir, surface and subsurface samples were collected along transects. Samples were collected along 3 transects which extended across the flood plain, perpindicular to the direction of flow. All of the transects were located below Brunswick Canyon in Dayton and Churchill Valley where the flood plain is most expansive and where there were no mills. The locations of the transects are illustrated in Figure 9 and 11 ("FP" sample areas). Along each transect, 10 surface soil samples were collected and analyzed for total mercury. At the Fort Churchill gage, samples were also collected from the different stratigraphic intervals apparent in the bank of the flood plain ("FP005").

In order to collect samples which represent the levels of mercury occurring on the flood plain below Lahontan Reservoir, surface and subsurface samples were also collected along transects. Six transects intersected the South Branch of the Carson River, the main channel of the Carson River before the construction of Lahontan Dam. Three transects intersected Stillwater Slough, a canal which conveys water from Carson Lake to Stillwater; and 5 transects intersected the New River Extension Drain which is presently an active irrigation channel below Lahontan Reservoir. The locations of these tansects are indicated in Figure 12. The number of samples ranged from 4 to 7 surface samples per transect and 0 to 2 subsurface samples.

Additional sampling was performed at locations on the flood plain, above and below Lahontan Dam, where mercury levels exceeded 25 ppm. At these locations, a 1.5 acre sampling area was defined on the flood plain with the original sample location near the center of this area. Nine surface soil samples were collected from this area at locations randomly selected on a grid pattern with 25 foot centers. This data set was then used to estimate exposure point concentrations for the flood plain. The sampling results for the flood plain are summarized in Tables B.5b and B.9.

The entire data set (n = 26) for the alluvial fan was used to derive exposure point concentrations for mercury. Exposure point concentrations for the flood plain were derived using the data from FP003 and FA010. These sampling areas included the highest mercury levels measured on the flood plain. The exposure point concentrations for the alluvial fan and the flood plain are presented in Table 6.4.

Exposure point concentrations for arsenic were derived to represent both the alluvial fan and the flood plain. Since arsenic levels on the alluvial fan and the flood plain are similar, exposure point concentrations were derived by combining data from both of these areas. The 95 UCL and the arithmetic mean were then used for high-end and typical estimates. These exposure point concentrations are included in Table 6.5.

Sampling results from the alluvial fan and flood plain are presented in Tabels B.7 through B.9.

Incidental Ingestion of Soil and Sediment Associated with Beach Deposits

Beach deposits associated with waterbodies such as Lahontan Reservoir, Washoe Lake, and Indian Lakes were recognized as separate areas of potential concern because beach deposits are formed by distinct physical processes (i.e., fluctuation of water levels and wind currents) and because these areas are more often used for recreation. The objective of this sampling was to estimate exposure point concentrations for soils and sediments at these areas.

Soil samples were collected from beach areas associated with Lahontan Reservoir, Indian Lakes, and Washoe Lake. Sampling at Lahontan Reservoir and Indian Lakes was performed by the U.S. Bureau of Reclamation (BOR, 1993a and 1993b). Sampling at Washoe Lake was performed by EPA. The sampling strategy applied by EPA and by BOR was to collect samples from beach areas that are frequently used for recreation. The sample size was not statistically based. Samples were analyzed for total mercury and for the other trace metals included on EPA's Target Analyte List (TAL). The sampling locations at and around Lahontan Reservoir are indicated in Figure 13 and the results are presented in Table B.11. The sampling locations for the Indian Lakes area are indicated in Figure 12 and the results are presented in Table B.12. The sample locations for Washoe Lake are indicated in Figure 14 and the results for the Washoe Lake sample areas are summarized in Table B.7.

Since mercury was not detected at levels of concern at any of the beach areas, exposure to mercury was not further evaluated for these areas. Since elevated arsenic levels were detected by BOR at Lahontan Reservoir beach areas, an exposure point concentration for arsenic was derived and exposure was further evaluated. With the data developed by BOR, the 95 UCL was used to estimate high-end exposure and the arithmetic mean was used to estimate typical exposure. The exposure point concentrations for arsenic are provided in Table 6.5.

Ground Water Ingestion

The objective of the ground water sampling was to determine if mercury is impacting ground water. The sampling strategy consisted of identifying domestic wells in the Mark Twain and Dayton where a potable ground water supply was developed. The aquifer formation which provides water to these communities is associated with the alluvial fan below Sixmile Canyon and the depth to the water table ranges from less than 20 feet near the Carson River to 200 feet on fan slopes away from the river (Glancy and Katzer, 1976). Based on the proximity of this aquifer to historic millsites in Sixmile Canyon and Dayton, EPA assumed that there was the highest potential for this aquifer to be impacted among all of the aquifers in the Carson Basin.

Water samples were collected from 32 homes in Mark Twain and Dayton where water is extracted directly from the alluvial fan aquifer. Samples were collected from taps located inside and outside of homes and samples were analyzed for total mercury, arsenic, and lead. Sampling locations are identified in Figure 15. The sample results for the ground water sampling are summarized in Table B.15.

Since mercury was not detected at levels exceeding the method detection limit (0.20 ug/l), exposure point concentrations were not derived for ground water and this exposure pathway was not further evaluated for mercury.

Arsenic was detected above the method detection limit (2.2 ug/l) at seven wells, one of which exceeded the background level (7 ug/l)[1]. From the well which exceeded the background level (DW002-GW-07), arsenic was measured at 138 ug/l on July 15, 1993 and was measured at 7.8 ug/l on August 18, 1994 when the well was resampled to verify the prior sampling results. A possible explanation for detecting elevated arsenic in 1993 is that this well may not have an effective filter pack, thus permitting high suspended solids in the water. The water sample collected in 1993 was discolored from high suspended solids while the sample collected in 1994 was clear. Given that ground water samples are not filter before they are analyzed, elevated arsenic may be associated with the suspended solids. Since elevated arsenic was only detected in this one well, which is not a drinking water source, ground water was not further evaluated as an exposure medium for arsenic.

[1] The background concentration for arsenic in ground water is based on the median concentration measured in ground water from the Carson Valley hydrographic area (Welch et. al., 1989).

Air Inhalation

The objective of the air sampling was to determine if air is a significant exposure pathway for mercury and to estimate exposure point concentrations for this pathway. The air pathway was recognized as a potential concern based on the high percentage of elemental mercury (Hg(0)) measured in the soil matrix (see Table B.2). Given the high vapor pressure of Hg(0) and the widespread occurrence of mercury in soils, this pathway was selected for further characterization. To evaluate this pathway, EPA performed indoor air sampling in Dayton. Indoor air sampling was considered the most direct and accurate method to evaluate mercury exposure via inhalation because homes tend to draw and contain air and because there is known human exposure.

Indoor air samples were collected according to the National Institute of Occupational Safety and Health (NIOSH) Method #6009. This method involves drawing air through an absorbent tube for approximately 8 hours and measuring the concentration of total mercury absorbed in the tube. Based on the volume of air sampled and the concentration of mercury absorbed, an air concentration is derived. One, 8 hour sample was collected from 13 homes and 4, 8 hour samples were collected from 2 homes in Dayton. The number of homes sampled and the location of the homes was determined based on the proximity of homes to millsites and the number of homes which provided access. The approximate air sampling locations are described in Figure 16 and the results are summarized in Table B.17.

As is indicated in Table B.17, mercury was not detected in any of the homes sampled. However, because the detection limit for this method (0.21 ug/m^3) is almost equal to EPA's reference concentration for subchronic and chronic toxicity (0.30 ug/m^3), this exposure pathway was evaluated. Per EPA's guidance (EPA 1989), the concentration of mercury in air is estimated to be half of the method detection limit and this value is used as the exposure point concentration. This exposure point concentration is provided in Table 6.4.

Indoor air sampling conducted by EPA did not measure mercury levels associated with suspended dust ("respirable dust"). However, exposure point concentrations for respirable dust were derived from data developed by BOR (BOR, 1993c) for Lahontan Reservoir beach areas. Without data, respirable dust concentrations can be estimated based on the levels of mercury measured in surface soil and a particulate emission factor (PEF). The PEF relates the mercury concentration in soil with the concentration of respirable particles (PM_{10}) in the air due to fugitive dust emissions. This relationship was derived by Cowherd (1985) for a rapid assessment procedure applicable to a site where surface contamination provides a relatively continuous and constant potential for emission over an extended period of time (i.e., years). The equation and parameters used to calculate a PEF are provided in

Appendix C. With the equation and default parameters provided in Appendix C, the PEF is calculated to be 4.63 x 10^9 m^3/kg. By dividing the 95 UCL for MS004-SA2 (the highest mercury concentrations measured in Dayton) by the PEF, the mercury concentration associated with respirable particles is estimated to be 3.10 x 10^{-5} ug/m^3. Applying the same procedure to TP007-SA (the highest concentrations measured among all of the historic millsites), the concentration associated with respirable particles is estimated to be 4.2 x 10^{-4} ug/m^3. Since both of these estimates are lower than the worst case concentration estimated by BOR (0.003 ug/m^3), the concentration derived by BOR was used as the exposure point concentration for respirable dust at all areas. This exposure point concentration is provided in Table 6.4.

An exposure point concentration for airborne arsenic was derived using data developed by BOR. Arsenic is not expected to volatilize from soils as is expected for mercury. Volatilization of inorganic arsenic at mine sites is only significant in extremely reducing environments where arsine gas (AsH_3) is formed (Woolson, 1977 and EPA, 1984b) which was not considered representative of the millsite areas. Therefore, inhalation of volatilized arsenic was not considered an exposure pathway of concern. Respirable particles were evaluated as an exposure medium for arsenic using the worst case concentration estimated by BOR (0.002 ug/m^3) (BOR, 1993c). Again, it was found that the concentrations estimated with the PEF and the maximum arsenic levels measured at historic millsites was less than the worst case concentrations estimated by BOR. This exposure point concentration is provided in Table 6.5.

Consumption of Domestic Produce or Bullrush Root

The objective of the produce sampling was to determine if plants are translocating mercury from soils and thereby creating a complete exposure pathway via consumption of domestic produce. The sampling objective was to develop a data set which describes the range of concentrations at which mercury occurs in vegetables and fruit commonly grown in domestic gardens. The sampling strategy consisted of seeking out domestic gardens and/or fruit trees in the vicinity of former millsites, measuring total mercury concentrations in the surrounding surface soil, and measuring total mercury concentrations in various vegetables and fruits available from the gardens where mercury was detected in the soil. All of the gardens were located in Dayton with exception for two fruit trees which were located in Silver City. The sampling locations in Dayton are indicated in Figure 17 and the results from the vegetable, fruit, and soil samples are presented in Table B.18.

In order to estimate the amount of environmental contaminants ingested with dietary intake of vegetables, vegetables are divided into four groups according to how the edible portion would be exposed to environmental contaminants. The four groups are as follows:

- *root vegetables* - edible portions which are derived from the root component of the plant, i.e., carrots, potatoes, and onions;
- *leafy vegetables* - edible portions which are derived from the leaf component of a plant, i.e., lettuce, cabbage, etc.,:
- *above ground protected* - edible portions which are formed above ground with the edible surface protected from direct exposure to the atmosphere, i.e., corn; and
- *above ground exposed* - edible portions which are formed above ground with the edible surface directly exposed to the atmosphere, i.e., tomatoes, green peppers, etc.,.

Exposure point concentrations were derived for each of these vegetable groups because dietary intake parameters are also broken out into these same four groups (Table E.7). Fruits were evaluated as a separate group. The arithmetic mean of wet weight concentrations were used for both high-end and typical exposure estimates. Half of the method detection limit was used for all nondetect samples. Given the small data set for each type of vegetable and fruit, it was not possible to calculate 95 UCLs for high-end exposure points. Rather than using maximum detected concentrations, it was determined that using the arithmetic mean for both the high-end and typical exposure point concentrations was more reasonable. The basis for this decision was that the intake parameters used for estimating high-end exposure (Table E.8) already provided for the highest exposure that is reasonably expected to occur via consumption of fruit and vegetables. The exposure point concentrations are provided in Table 6.4.

Based on phone interviews, it was determined that bullrush roots ("tules") are consumed by some residents of the Fallon Paiute Reservation. With data developed by Hoffman et. al., 1990 (Table B.19) for Carson Lake, this exposure pathway was qualitatively evaluated. The maximum concentration was used for a high-end estimate and the arithmetic mean was used for a typical estimate. These exposure point concentrations are provided in Table 6.4.

Vegetable and fruit samples were not analyzed for arsenic because arsenic was not initially identified as a contaminant of potential concern. Thus, this exposure medium was not quantitatively evaluated for arsenic.

Consumption of Fish and Waterfowl

This phase of the RI did not include fish and waterfowl sampling to assess human exposure to mercury because sufficient data was available from existing sources to serve this purpose. The sources of fish and waterfowl data used for this HHRA are as follows:

- Cooper, J.J., R.O. Thomas, and S.M. Reed, 1985, Total Mercury in Sediment, Water, and Fishes in the Carson River Drainage, West Central Nevada;

- Hoffman, R.J., R.J. Hallock, T.G. Rowe, M.S. Lico, H.L. Vurge, and S.P. Thompson, 1990, Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in and near Stillwater Wildlife Management Area, Churchill County, Nevada, 1986-1987: U.S. Geological Survey Water Resources Investigation Report 89-4105;

- Nevada Department of Wildlife, 1986, Statewide Fisheries Management Program, Lahontan Reservoir, Job No. 102;

- Nevada Division of Environmental Protection, Annual Monitoring for mercury levels in fish in Lahontan Reservoir;

- Rowe, T.G., Lico, M.S., Hallock, R.J., Maest, A.S., and Hoffman, R.J, Physical, Chemical, and Biological Data for Detailed Study of Irrigation Drainage in and near Stillwater, Fernley, and Humboldt Wildlife Management Areas and Carson Lake, West-Central Nevada, 1987-89: U.S. Geological Survey, Open File Report 91-185; and

- Tuttle, Peter, September 1992, Mercury in Fish Collected from the Indian Lakes System Stillwater Wildlife Management Area Churchill County, Nevada: U.S. Fish and Wildlife Service;

The data from these sources are summarized in Tables B.20 through B.24.

The method used to derive exposure point concentrations for fish was to select an indicator species for different parts of the Carson River and Washoe Lake and derive exposure point concentrations using the mercury levels measured in the muscle tissue of the indiator species. Indicators species were selected to represent the Carson River above Lahontan Reservoir, Lahontan Reservoir, the Carson River below Lahontan Dam, Indian Lakes, and Little Washoe Lake. In most cases, the indicator species were selected to represent the species highest on the food chain. For Lahontan Reservoir, walleye were selected over bass because mercury levels were consistently higher than the levels in white bass. Also, according to the Nevada Department of Wildlife (Sevon, 1994) walleye have more successfully endured the drought which extended from 1987 to 1992. The indicator species selected for the different fisheries are presented in Table 6.3.

TABLE 6.3: Indicator Fish Species for Exposure Assessment	
Fishery	**Indicator Species**
Carson River above Lahontan	White Bass
Lahontan Reservoir	Walleye
Carson River below Lahontan	White Bass
Indian Lakes	White Bass
Little Washoe Lake	White Bass

With the data provided in Table B.20 and 21, exposure point concentrations were derived for the each fishery. In all cases, the arithmetic mean was used for both high-end and typical exposure estimates because exposure is assessed based on one species of fish. Thus, it was assumed that the selected indicator species is the only fish caught and consumed from the Carson River system. Since this is already a conservative assumption, it was considered more reasonable to use the arithmetic mean for estimating high-end expsosure. Data developed by Cooper et. al., 1985 at Fort Churchill was used for the Carson River above Lahontan Reservoir; data developed by NDOW from 1984 through 1990 was used for Lahontan Reservoir; data developed by Cooper et. al., 1985 was used for the Carson River below Lahontan Reservoir; data developed by USFWS, 1993 was used for Indian Lakes; and data developed by NDEP, 1987 was used for Little Washoe Lake. These exposure point concentrations are provided in Table 6.4.

Using the data presented in Tables B.22 through B.24, exposure point concentrations were derived for shovelers, mallards, and green-wing teal from Carson Lake and for mallards and shovelers from Stillwater. All of the exposure point concentrations were derived using data developed by Rowe et. al., 1991. Exposure point concentrations were derived from the arithmetic mean and the 95 UCL for wet weight concentrations. These exposure point concentrations for waterfowl are provided in Table 6.4.

Fish and waterfowl were not considered as exposure media of concern for arsenic. The conversion of inorganic arsenic to organic forms in aquatic organisms and in sediments, in contrast to mercury, represents a detoxification mechanism (Arnold, 1988 and Irgolic, 1982). Also, unlike mercury, arsenic is readily excreted by most food chain organisms, thus limiting its potential for bioaccumulation (EPA, 1984b). The potential for arsenic to bioconcentrate in aquatic species is approximately 100 times less than that of inorganic and organic mercury compounds. It is noted that arsenic can bioconcentrate to some extent in lower-level food chain organisms (Woolson, 1977).

6.2.3 CHARACTERIZE MERCURY LEVELS IN SOILS AT AND AROUND HISTORIC MILLSITES

The purpose for this sampling was to determine if mercury levels in soils at and around historic millsites and extant tailing piles were significant. For this purpose, significant is defined as exceeding the PRG for mercury in soils, 25 ppm (EPA, 1991). This sampling was intended to serve as a screening process for identifying where soil remediation should be evaluated. The sampling strategy was to collect a representative number of surface and subsurface samples from each millsite or tailing pile. The soil samples were collected from locations where mercury was thought likely to occur (i.e., ostensible tailings material, tailing ponds, ruins, etc.). The number of samples collected from each area ranged from 5 to 25 surface samples and 1 to 5 subsurface samples. The sampling areas are described in Figures 18 through 22 and the results are presented in Table B.4.

The data sets for each discrete sampling area were evaluated by comparing the concentrations of mercury measured in surface soil with the preliminary remediation goal of 25 ppm. Sampling areas where there were no sample results greater than or equal to 25 ppm were screened out of further evaluation. For sampling areas where there were more than two sampling locations equal to or greater than 25 ppm, a subarea was defined with the sampling results equal to or greater than 25 ppm and the data included within this subarea was used to calculate statistical values (i.e., arithmetic mean). Subareas were not defined for sampling areas where there was only one or two samples equal to or greater than 25 ppm, unless the sample(s) could be grouped with an adjacent subarea. Also, if two adjacent samples measured above 25 ppm, a line between the two points was buffered to create a subarea. Through this process, 39 subareas were selected for further evaluation. These subareas are described in Figure 10 and Figures 23 - 27. The statistical values for these subareas are summarized in Table B.13.

TABLE 6.4: Summary of Exposure Point Concentrations for Mercury				
Type of Exposure/Area of Concern	**Data Set**	**Area Represented**	**Derivation Method**	**Exp. Pt. Conc.**
Soil Ingestion/Millsites in Residential Areas	MS004-SA	Dayton	95 UCL[a]	231 mg/kg
			Arithmetic Mean	149 mg/kg
Soil Ingestion/Millsites in Open Land Use Areas	MS015-SA	Brunswick Canyon	95 UCL	779 mg/kg
			Arithmetic Mean	486 mg/kg
	TP007-SA	Sixmile Canyon	95 UCL	1436 mg/kg
			Arithmetic Mean	1007 mg/kg
Soil Ingestion/Alluvial Fan	AF001	Alluvial Fan	95 UCL	57 mg/kg
			Arithmetic Mean	37 mg/kg
Soil Ingestion/Flood Plain Above Lahontan	FP003	Flood Plain above Lahontan	95 UCL	48 mg/kg
			Arithmetic Mean	25 mg/kg
Soil Ingestion/Flood Plain Below Lahontan	FA001	Pre-Lahontan Carson River Flood Plain	95 UCL	15 mg/kg
			Arithmetic Mean	10 mg/kg
	FA009	Stillwater Slough	95 UCL	42 mg/kg
			Arithmetic Mean	25 mg/kg
	FA010-SA	Modern Carson River Flood Plain	95 UCL	178 mg/kg
			Arithmetic Mean	90 mg/kg
Inhalation of Suspended Dust/Millsites in Residential & Recreation Areas	BOR, 1993	Lahontan Reservoir	Maximum	0.003 ug/m^3
Inhalation of Volatilized Mercury/Millsites in Residential & Recreation Areas	DA01AV-001 - DA01AV-026	Dayton	1/2 Method Detection Limit	0.11 ug/m^3

TABLE 6.4: Summary of Exposure Point Concentrations for Mercury				
Type of Exposure/Area of Concern	**Data Set**	**Area Represented**	**Derivation Method**	**Exp. Pt. Conc.**
Consumption of Domestic Produce, Root Vegetables/Dayton	AG004-VG-01A AG004-VG-02A AG007-VG-02A AG007-VG-04A	Domestic Gardens in Dayton	Arithmetic Mean	0.27 mg/kg (wet wt.)
Consumption of Domestic Produce, Leafy Vegetables/Dayton	AG002-VG-02A AG002-VG-03A AG007-VG-01A	Domestic Gardens in Dayton	Arithmetic Mean	0.03 mg/kg (wet wt.)
Consumption of Domestic Produce, Above Ground Protected Vegetables/Dayton	AG007-VG-05A	Domestic Gardens in Dayton	Arithmetic Mean	0.07 mg/kg (wet wt.)
Consumption of Domestic Produce, Above Ground Exposed Vegetables/Dayton	AG002-VG-01A AG002-VG-04A AG004-VG-03A AG004-VG-04A AG005-VG-01A AG005-VG-02A AG005-VG-03A AG007-VG-03A	Domestic Gardens in Dayton	Arithmetic Mean	0.02 mg/kg (wet wt.)
Consumption of Domestic Produce, Fruit/Dayton	AG005-VG-04A AG009-VG-01A AG009-VG-02A AG009-VG-03A	Domestic Gardens in Dayton	Arithmetic Mean	0.04 mg/kg (wet wt.)
Consumption of Bullrush Root/Carson Lake	Hoffman et. al., 1990	Carson Lake	Arithmetic Mean	0.08 mg/kg (wet wt.)
			Maximum	0.32 mg/kg (wet wt.)

TABLE 6.4: Summary of Exposure Point Concentrations for Mercury				
Type of Exposure/Area of Concern	**Data Set**	**Area Represented**	**Derivation Method**	**Exp. Pt. Conc.**
Consumption of White Bass/Carson River and Indian Lakes	Cooper et. al., 1985	Carson River Above Lahontan	Arithmetic Mean	3.14 mg/kg (wet wt.)
	Cooper et. al., 1985	Carson River Below Lahontan	Arithmetic Mean	1.00 mg/kg (wet wt.)
	USFWS, 1993	Indian Lakes	Arithmetic Mean	2.00 mg/kg (wet wt.)
Consumption of White Bass/Little Washoe Lake	NDEP, 1987	Washoe Lake	Arithmetic Mean	0.58 mg/kg (wet wt.)
Consumption of Walleye/Lahontan Reservoir	NDOW, 1984-1990	Lahontan	Arithmetic Mean	2.36 mg/kg (wet wt.)
Consumption of Shovelers/Carson Lake and Stillwater	Rowe et. al., 1991	Carson Lake	Arithmetic Mean	2.68 mg/kg (wet wt.)
			95th percent UCL	3.65 mg/kg (wet wt.)
		Stillwater	Arithmetic Mean	0.89 mg/kg (wet wt.)
			95th percent UCL	1.45 mg/kg (wet wt.)
Consumption of Mallards/Carson Lake and Stillwater	Rowe et. al., 1991	Carson Lake	Arithmetic Mean	0.49 mg/kg (wet wt.)
			95th percent UCL	1.05 mg/kg (wet wt.)
		Stillwater	Arithmetic Mean	0.32 mg/kg (wet wt.)
			95th percent UCL	0.88 mg/kg (wet wt.)
Consumption of Green Wing Teal/Carson Lake	Rowe et. al., 1991	Carson Lake	Arithmetic Mean	0.71 mg/kg (wet wt.)
			95th percent UCL	1.27 mg/kg (wet wt.)

TABLE 6.5: Summary of Exposure Point Concentrations for Arsenic				
Type of Exposure/Area of Concern	**Data Set**	**Area Represented**	**Derivation Method**	**Exp. Pt. Conc.**
Soil Ingestion/Millsites in Residential Areas	MS002	Dayton	95 UCL[a]	42 mg/kg
			Arithmetic Mean	25 mg/kg
	TP002, TP004, TP006, TP007, TP008, TP011, TP012, TP013, TP014, TP015, TP016, TP017, TP019, TP020, TP021	Sixmile Canyon	95 UCL	119 mg/kg
			Arithmetic Mean	55 mg/kg
Soil Ingestion/Alluvial Fan and Flood Plain	AF001, FP002, FP003, FP004	Alluvial Fan and Flood Plain above Lahontan Reservoir	Arithmetic Mean	10 mg/kg
			Maximum	17 mg/kg
Soil Ingestion/Lahontan Reservoir	BOR, 1993	Lahontan Reservoir beach areas	95 UCL	17 mg/kg
			Arithmetic Mean	10 mg/kg
Inhalation of Suspended Dust/All areas	BOR, 1993	Lahontan Reservoir beach areas	Maximum	0.002 ug/m^3
a. 95th percent upper confidence limit for normal distribution.				

Arsenic and lead were not initially recognized as contaminants of potential concern. Thus, fewer samples from historic millsites were analyzed for these metals. Arsenic and lead data for the historic millsites are summarized in Tables B.5 and B.6, respectively. Levels of arsenic and lead were evaluated using the respective PRGs which are 23 mg/kg for arsenic and 500 mg/kg for lead. If the the maximum concentration of arsenic or lead measured at a millsite exceeded the respective PRG and the area is within a residential area, then the area was retained for further evaluation.

6.3 DATA EVALUATION AND QUALITY ASSURANCE/QUALITY CONTROL METHODS

The procedures followed to ensure precision, accuracy, representativeness, completeness, and comparability of all of the data developed by EPA for this operable unit are described in the "Quality Assurance Project Plan for Phase I of the RI/FS for the Carson River Mercury Site" dated March 9, 1993 (Document Control No. ZS3142.2.2) prepared by Ecology and Environment, Inc. The quality assurance procedures employed by BOR for sampling and analyzing soil and sediment from Lahontan Reservoir, Carson Lake, and Indian Lakes and for sampling respirable particulates were reviewed by EPA and were found to be acceptable for risk assessment data. The quality assurance procedures employed by USGS, USFWS, NDEP, and NDOW for sampling and analyzing mercury levels in fish and waterfowl were not reviewed by EPA. However, given the size of the data sets from these sources, it was determined that this was the best available data for estimating exposure to mercury via fish and waterfowl ingestion. Data validation reports for the data developed by EPA and BOR are provided in Appendix H.

7.0 EXPOSURE ASSESSMENT

This section presents the exposure assessment which is the identification and evaluation of potentially complete exposure pathways. Potentially complete exposure pathways are identified based on the location of contamination, the affected media, and land use. Exposure pathways are quantitatively and/or qualitatively evaluated based on the concentrations at which the contaminants occur in the environment at a particular area and the land use for that area. The land use determines the type of exposure, the frequency of exposure, the duration of exposure, and identifies the potentially exposed population. Based on the information and data presented in Sections 4.0, 5.0, and 6.0, this section identifies the potentially complete exposure pathways and evaluates the significance of these pathways.

7.1 IDENTIFICATION OF EXPOSURE PATHWAYS

In order to identify the potentially complete exposure pathways which should be evaluated as part of this HHRA, all of the potential exposure pathways are presented and screened in this section. The purpose for this approach is to clearly present the rationale for selecting exposure pathways for evaluation.

A complete human exposure pathway must include the following four elements for each chemical of concern:

- a source and mechanism of chemical release to the environment (i.e., tailings discharge from a mill);
- an environmental transport and exposure medium (i.e., surface water, air, ground water, etc.);
- a type of land use which creates human contact with the contaminated medium; and
- a human exposure route (i.e., ingestion).

Historical information and environmental data confirm that Comstock mills released mercury to the environment and that the mercury released from these milling operations is widely distributed in the environment due to various transport mechanisms. Also, based on the elevated levels of arsenic detected in soils at and around historic millsites, it was concluded that mill tailings also contained elevated levels of arsenic. In this section, potentially complete exposure pathways are identified according to the human exposure routes of concern and land use.

7.1.1 EXPOSURE ROUTES OF POTENTIAL CONCERN

Based on the contaminants of concern and the affected media, Table 7.1 identifies the exposure routes of potential concern for the different media. The five pathways which are identified as important are evaluated for the different populations and areas of potential concern described in Section 5.0. The rationale for omitting the other human exposure routes from the exposure assessment is described herein.

TABLE 7.1: Exposure Routes of Potential Concern

MEDIUM	HUMAN EXPOSURE ROUTE		
	Ingestion	*Inhalation*	*Dermal Absorbtion*
Soil/Dust	yes	yes	no
Sediment	no	no	no
Surface Water	no	no	no
Ground Water	no	no	no
Air	no	yes	no
Fish and/or Waterfowl	yes[1]	no	no
Local produce/Tules	yes	no	no

1. Fish and waterfowl are only a potential exposure medium for mercury.

Ingestion

Sediment: In order for ingestion of sediment to be an exposure pathway of concern, mercury concentrations in sediment should exceed 25 ppm and a person should be ingesting a minimum of 100 mg of sediment per day. Based on the levels described in Table B.14, mercury levels in sediment generally do not exceed 25 ppm. Secondly, given that sediment are generally immersed in water, it is considered unlikely that either a person could manage to ingest up to 100 mg of sediment per day under plausible scenarios. Thus, this pathway was not evaluated for either mercury or arsenic.

Ground Water: Ingestion of ground water was initially recognized as a potential exposure pathway for mercury because historic millsites and extant tailing piles are located over aquifers that are drinking water sources. However, since mercury and arsenic were not detected at levels of concern in drinking water (Table B.13), this exposure pathway was not further evaluated for mercury and arsenic.

Surface Water: Surface water was not recognized as an exposure medium of concern for mercury because the Carson River system is not a drinking water source for any human populations. Therefore, ingestion of surface water only occurs during swimming or other recreation activities. Surface water samples collected near Fort Churchill on October 30, 1993, measured 0.277 and 0.290 micrograms per liter (ug/l)[1] total mercury. Although these are relatively high concentrations of mercury in surface water, these levels are not significant according to the National Drinking Water Standard for mercury (MCL = 2.0 ug/l (EPA, 1986a)). Also for the same reasons, this exposure medium was screened out for arsenic. Data developed by BOR for Lahontan Reservoir (Table B.14) demonstrated that arsenic in surface water does not exceed the National Drinking Water Standards (MCL=50 ug/l (EPA, 1986a)). It is noted that arsenic levels as high as 692 ug/l were detected in surface water from Indian Lakes (BOR, 1993b). However, for the reasons discussed in Section 6.2.1, human health risks associated with exposure to arsenic were not evaluated for the Carson Desert hydrographic area.

Air: The intake parameters used to estimate soil ingestion also represents ingestion of suspended dust. Therefore, this exposure pathway is evaluated with the evaluation of soil ingestion.

Inhalation

Sediment: When sediments are immersed in water, it is considered unlikely that mercury or arsenic in sediments could either be volatilized or suspended by wind whereby mercury levels in ambient or indoor air would be at levels of concern. However, during low water years, exposed sediments become a significant source of suspended dust. For this reason, inhalation of respirable particulate dust was evaluated for both mercury and arsenic in this HHRA.

Surface Water and Ground Water: Inhalation was not considered a plausible human exposure route for surface water or ground water.

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[1] These water samples were collected and analyzed according to "ultra-clean" sampling protocol as part of a preliminary survey of the Carson River for the ecological assessment (Mach, 1993).

Biota: Inhalation was not considered a plausible human exposure route for biota.

Dermal Absorption

Surface and Ground Water: Since inorganics such as mercury and arsenic are poorly absorbed in dilute solutions, dermal exposure to surface water and ground water was not evaluated in this HHRA.

Air: Dermal absorption was not considered a plausible human exposure route for air.

Biota: Dermal absorption was not considered a plausible human exposure route for either flora or fauna.

7.1.2 POTENTIALLY COMPLETE EXPOSURE PATHWAYS

Given the five types of exposure described in Table 7.1, Tables D.1 through D.3 identifies the potentially complete exposure pathways according to the populations of potential concern, the areas of concern, and the different types of land use.

7.1.3 SCREENING AND SELECTION OF POPULATIONS AND LAND USE FOR EVALUATING EXPOSURE PATHWAYS

A large number of the pathways identified in Tables D.1 through D.3 are essentially the same with exception for the receptor population. The process described in Figure 28 was used to select the population and land use for evaluating these exposure pathway. Table 7.2 describes the populations and land use selected for evaluating exposure pathways and indicates if the pathway was quantitatively evaluated.

7.2 EVALUATION OF EXPOSURE PATHWAYS

In this section, the pathways identified in Table 7.2 are quantitatively evaluated. The purpose for the quantitative evaluation is to estimate the amount of chemical "available at human exchange boundaries (i.e., lungs, gut, skin) (EPA, 1989a)" over a specified exposure period. This estimate is based on the environmental data presented in Section 6.0 and the degree of contact that a human receptor will potentially have with the media. For exposure pathways which are quantitatively evaluated, exposure is estimated as a daily intake per unit body weight.

7.2.1 EQUATIONS FOR QUANTITATIVELY EVALUATING EXPOSURE PATHWAYS

Chronic daily intakes, expressed in micrograms of chemical per kilogram of body weight per day (ug/kg-day), are calculated using formulas defined in RAGS (EPA, 1989a) and are used to evaluate exposure. The specific chemical intake equations used to quantitatively evaluate exposure pathways for this exposure assessment were as follows:

- *Ingestion of Chemicals in Soil for Residential Exposure;*
- *Inhalation of Airborne Chemicals for Residential Exposure;*
- *Ingestion of Contaminated Fruits and Vegetables for Residential Exposure;*
- *Ingestion of Contaminated Fish for Residential Exposure; and*
- *Ingestion of Contaminated Waterfowl for Residential Exposure.*

These equations are described in Appendix E.

TABLE 7.2: SELECTION OF PATHWAYS FOR QUANTITATIVE EVALUATION				
TYPE OF EXPOSURE PATHWAY/AREA OF CONCERN	POPULATION OF POTENTIAL CONCERN	LAND USE	QUANT. EVAL	COMMENTS
Soil Ingestion/Floodplain AL	Dayton	Residential	yes	
Produce Consumption/Floodplain AL	Dayton	Residential	no	Evaluated based on sampling of domestic produce in Dayton.
Dust Inhalation/Floodplain AL	Dayton	Residential	no	Evaluated based on data developed by BOR, 1993.
Vapor Inhalation/Floodplain AL	Dayton	Residential	no	Evaluated based on air sampling conducted in Dayton.
Soil Ingestion/Floodplain BL	Fallon	Residential	yes	
Produce Consumption/Floodplain BL	Fallon	Residential	no	Evaluated based on sampling of domestic produce in Dayton.
Dust Inhalation/Floodplain BL	Fallon	Residential	no	Evaluated based on data developed by BOR, 1993.
Vapor Inhalation/Floodplain BL	Fallon	Residential	no	Evaluated based on air sampling conducted in Dayton.
Soil Ingestion/Millsites	Dayton	Residential	yes	
Produce Consumption/Millsites	Dayton	Residential	yes	
Dust Inhalation/Millsites	Dayton	Residential	yes	Quantitatively evaluated based on data developed by BOR, 1993.
Vapor Inhalation/Millsites	Dayton	Residential	yes	

TABLE 7.2: SELECTION OF PATHWAYS FOR QUANTITATIVE EVALUATION				
TYPE OF EXPOSURE PATHWAY/AREA OF CONCERN	**POPULATION OF POTENTIAL CONCERN**	**LAND USE**	**QUANT. EVAL**	**COMMENTS**
Soil Ingestion/Alluvial	Mark Twain	Residential	yes	
Produce Consumption/Alluvial	Mark Twain	Residential	no	Evaluated based on sampling of domestic produce in Dayton.
Dust Inhalation/Alluvial	Mark Twain	Residential	no	Evaluated based on data developed by BOR, 1993.
Vapor Inhalation/Alluvial	Mark Twain	Residential	no	Evaluated based on air sampling conducted in Dayton.
Soil Ingestion/Millsites in Recreation Areas	Dayton	Recreational	yes	Evaluated based on data from the Six Mile Canyon and Carson River millsites.
Dust Inhalation/Millsites in Recreation Areas	Dayton	Recreational	yes	Quantitatively evaluated based on data developed by BOR, 1993.
Vapor Inhalation/Millsites in Recreation Areas	Dayton	Recreational	yes	Quantitatively evaluated based on air sampling conducted in Dayton.
Fish Consumption/Carson AL	Dayton	Residential	yes	Quantitatively evaluated based on data developed by Cooper et. al., 1985.
Soil Ingestion/Lahontan	Dayton	Recreational	yes	Quantitatively evaluated for arsenic based on data developed by BOR, 1993.
Tules Consumption/Carson Lake	Fallon Paiute Reservation	Residential	no	Evaluated based on sampling of domestic produce in Dayton.

TABLE 7.2: SELECTION OF PATHWAYS FOR QUANTITATIVE EVALUATION				
TYPE OF EXPOSURE PATHWAY/AREA OF CONCERN	**POPULATION OF POTENTIAL CONCERN**	**LAND USE**	**QUANT. EVAL**	**COMMENTS**
Fish Consumption/Lahontan	Dayton	Residential	yes	Quantitatively evaluated based on data developed by NDOW, 1984 - 1990
Soil Ingestion/Washoe	Washoe	Recreational	no	Pathway was screened out based on data presented in Section 6.0.
Dust Inhalation/Washoe	Washoe	Residential	no	Evaluated based on data developed by BOR, 1993.
Vapor Inhalation/Washoe	Washoe	Residential	no	Evaluated based on air sampling conducted in Dayton
Fish Consumption/Washoe	Washoe	Residential	yes	Quantitatively evaluated based on data developed by NDEP, 1987
Fish Consumption/Carson BL	Fallon	Residential	yes	Quantitatively evaluated based on data developed by Cooper et. al., 1985.
Waterfowl Consumption/Carson Lake	Fallon	Residential	yes	Quantitatively evaluated based on data developed by Rowe et. al., 1992
Soil Ingestion/Indian Lakes	Fallon	Recreational	no	Pathway was screened out based on data developed by BOR, 1993.
Fish Consumption/Indian Lakes	Fallon	Residential	yes	Quantitatively evaluated based on fish data developed by USFWS, 1993.
Waterfowl Consumption/Stillwater	Fallon	Residential	yes	Quantitatively evaluated based on waterfowl data developed by Rowe et. al., 1992.

7.2.2 INTAKE PARAMETERS

The basic parameters used to calculate chemical intake for all of the exposure pathways are as follows:

- *the representative exposure point concentration;*
- *the representative physique (i.e., average weight, skin surface area) of the receptor;*
- *the rate at which a contaminant is ingested, inhaled, or absorbed upon contact with a medium (i.e., liters of water ingested per day);*
- *how long and how often contact occurs with the contaminated medium (i.e., number of days water is ingested from a contaminated source and for how many years); and*
- *the unit period over which exposure is estimated (days).*

With exception for the exposure point concentrations and the ingestion rates for fish and waterfowl which were derived from site specific information, the parameters are standard assumptions. The standard assumptions for intake values are specific to exposure routes and potential receptors and are derived from specific studies and/or from national statistics.

For Superfund exposure assessments, intake values used to evaluate all of the exposure pathways are selected so that the combination of all the intake variables result in a "high-end" estimate and a "typical" estimate (EPA, 1989a). The purpose is to develop a range of estimates for each type of exposure. The high-end is "the highest exposure that is reasonably expected to occur at a site" and is intended to "estimate a conservative exposure case (i.e., well above the average case) that is still within the range of possible exposures (EPA, 1989)." The typical estimate is intended to approximate a more average case than the high-end estimate but is still recognized as a conservative evaluation.

The intake parameters for both high-end and the typical estimates are provided in Tables E.1 through E.7 and are discussed herein according to the type of exposure. Most of the intake parameters presented in these tables are taken from EPA's *Exposure Factors Handbook* dated March 1990 which describes the studies and assumptions used to develop these intake parameters. Other sources of intake parameters are also referenced in the tables.

<u>Soil Ingestion</u>

Soil ingestion scenarios were evaluated for residential and recreational land use. For residential land use, exposure via soil ingestion is evaluated for a young child (1 - 6 years), a school age child (7 -

18 years), and an adult. A young child is considered the most susceptible receptor for residential land use because children tend to ingest more dirt than a school age child or an adult (EPA 1990a). A school age child presents the worst case for recreational land use because school age child are assumed to visit recreation areas most frequently. Carcinogenic risks related to arsenic are evaluated for an adult (lifetime resident), a young child, and a school age child.

Typical and high-end intake parameters for the different receptor/land use scenarios are described in Table E.1. With exception for the high-end exposure frequency for recreational land use, all of the estimates provided in Table E.1 were taken directly from EPA's *Exposure Factors Handbook*. Studies suggest that outdoor recreation activities generally occur from May through October (6 months per year) (EPA, 1990a). Based on the assumption that recreational areas are visited two days per week for six months per year, the high-end exposure frequency was estimated to be 52 days per year. The exposure frequency for residential land use is estimated to be seven days per week for the entire year with exception for two weeks allotted for vacation, approximately 350 days per year (EPA, 1990a).

Air Inhalation

Air inhalation was evaluated for residential and recreational land use. As with soil ingestion, residential land use was evaluated for a child, a school age child, and an adult. Again, the school age child was considered to present the worst case scenario for recreation land use. Carcinogenic risks related to arsenic are evaluated for an adult (lifetime resident), a young child, and a school age child.

The typical and high-end intake parameters for the different receptor/land use combinations are described in Table E.2. The air inhalation rates for residential land use combine indoor and outdoor activities in the residential setting (EPA, 1990a). The inhalation rate for a school-age child/recreational land use scenario is based on breathing during typical recreation activities (i.e., hiking) (EPA, 1990a). As with soil ingestion, the exposure time for recreational land use was estimated to be 3 hours per day and the high-end exposure frequency was estimated to be 52 days per year. For residential land use, the exposure time was assumed to be 24 hours per day and the exposure frequency was estimated to be 350 days per year (EPA, 1990a). The exposure duration, body weight, and averaging time were also taken directly from the *Exposure Factors Handbook*.

Consumption of Vegetables, Fruit and Tules

Exposure associated with consumption of domestic produce was quantitatively evaluated for residential land use with a young child, school age child, and an adult as the receptors. For all types of vegetables and fruit, studies indicate that an adult has a larger consumption rate than young children or school-age children (USDA, 1982 and EPA, 1990a).

The typical and high-end intake parameters are described in Tables E.3 and E.4. The consumption rates presented in these tables were estimated based on average intake rates for more than 100 vegetables in the Dietary Risk Evaluation System (DRES) compiled by EPA (EPA, 1990a). As is described in the tables and in Section 6, ingestion rates are provided for four categories of vegetables: root vegetables, leafy vegetables, above ground protected vegetables and above ground exposed vegetables; and for fruit. The exposure frequency values are based on daily consumption of fruit and vegetables (350 days per year). The typical estimate for the fraction of an individual's fruit and vegetable diet that is homegrown is 25% and the high-end estimate is 40% (EPA, 1990a). The exposure duration, body weight, and averaging time are consistent with the assumptions provided for the other types of exposure.

Consumption of Fish

Fish consumption was only evaluated for an adult, partly because the amount of fish consumed by a person is assumed to be proportional to their body weight. Moreover, a young child is not included as a receptor because it is undetermined whether the Reference Dose (RfD) for methyl mercury is sufficiently health protective for unborn or young children in critical stages of development (WHO, 1990, ATSDR, 1992, and Stern, 1993) (see Section 8). Typical and high-end exposure estimates were determined for recreational land use (sport fishing) and a high-end exposure estimate was determined for subsistent fishing.

The typical and high-end intake parameters are described in Table E.6. The adult consumption rates presented in these tables were estimated based on the fish data presented in Section 6.0 and angler statistics developed by the Nevada Department of Wildlife for Churchill County (Table E.5). A high-end estimate for adult ingestion was derived from angler statistics for 1986 (19.44 fish/angler) and the reported mean weight for walleye (1,627 grams) presented in Table B.18 (Sevon, 1993). The typical estimate was determined based on the average fish per angler over the ten year survey period (11.32 fish/angler) and the average weight of walleye measured in 1986, 1988, 1989 (approximately 1495 grams per fish). For both estimates, it was assumed that all of the fish caught per angler is consumed by one individual. Based on information provided by NDOW, it was assumed that 50% of of the fish is consumed (Henry, 1994). The high-end ingestion rate for subsistent fishing was taken from EPA's *Exposure Factors Handbook*. The exposure frequency values are based on daily consumption of fish (350 days per year). The exposure duration, body weight, and averaging time were consistent with the assumptions provided for the other types of exposure.

Consumption of Waterfowl

Consumption of waterfowl was only evaluated for an adult and recreational hunting. The typical and high-end intake parameters for a recreation hunter are described in Table E.6. The consumption rates presented in these tables were estimated using waterfowl data developed by the Nevada Department of Wildlife (Saake, 1994). Based on bird hunter statistics developed by NDOW for 1973 through 1992, the average number of hunters who receive a license each year is 3,206 and the average number of birds bagged each year is 34,889 (approximately 11 birds per hunter per year). Also based on NDOW statistics, 32% of the birds bagged from Carson Lake are green-wing teal, 28% are pintail, 22% are mallards, and 18% are shovelers (Saake, 1994). According to data developed by Nelson and Martin (1953), the average weight of adult shovelers is approximately 612 grams, the average weight of adult green-wing teal is approximately 340 grams, and the average weight of adult pintails is approximately 906 grams. Data developed by Bellrose and Hawkins (1947) describes the average weight of adult mallards as approximately 1261 grams. With this data, the average weight of a bird bagged from Carson Lake was derived by multiplying the average weight of each species of waterfowl by the relative percent bagged from Carson Lake (approximately 750 grams per bird). An ingestion rate for both typical and high-end exposure was then derived assuming that 50% of each type of waterfowl is edible (Henry, 1994). Again, it was assumed that all of the birds bagged by a hunter are consumed by one individual. The exposure frequency values are based on daily consumption (350 days per year). The exposure duration, body weight, and averaging time were consistent with the assumptions provided for the other types of exposure.

7.2.3 QUANTITATIVE EVALUATION OF CHRONIC DAILY INTAKE

Chronic daily intakes (CDIs) were calculated for mercury and arsenic. In accordance with RAGS (EPA 1989a), daily intakes are calculated by multiplying the chemical concentration in the medium by the intake factor for that medium. For noncancer risks, a CDI is averaged over the duration of exposure and this value is used to evaluate the significance of exposure. For cancer risks, a CDI is averaged over an entire lifetime (assumed to be 70 years for an adult resident (EPA, 1990a))

In order to define a range of exposure levels, CDIs were calculated using typical exposure estimates and high-end exposure estimates. The calculated CDIs are presented in Tables 7.3 through 7.6. Table 7.4 describes the CDIs estimated for the different types of vegetables and for fruit. The total intake of fruit and vegetables is included in Table 7.3.

7.2.4. Adjustment of Chronic Daily Intakes

A refinement of the oral intake assumptions (known as adjusted intakes) to reflect bioavailability is an option (RAGS, 1989a). Bioavailability reflects the degree to which metal species are available for absorption following ingestion. In the following discussion, the difference in oral absorption between mercury species in soils and mercury species used to derive EPA's reference dose is discussed as a basis for adjusting pathway-specific CDIs.

Mercury

In general, there is a positive relationship between the solubility of the mercury species and their bioavailability (Stokinger, 1981; Von Burg and Greenwood, 1991). However, the quantitative relationship between solubility and bioavailability is difficult, if not impossible, to predict without empirical studies. Elemental mercury has the lowest solubility and lowest oral bioavailability (estimated at below 0.01%) and mercuric chloride has the highest solubility and highest bioavailability, estimated at 15% for adults (Rahola et al. 1971 and Task Group on Metal Accumulation 1973) and as high as 38% for young suckling animals (Kostial et al. 1978).

Mercuric sulfide present in site soils is estimated to have an absorption value that is less than that of mercuric chloride and greater than that of elemental mercury. Based on parallel studies of mercuric sulfide and the more soluble mercuric chloride (Weast 1985), mercuric sulfide is estimated to have a relative absorption value of 1/5th to 1/80th that of mercuric chloride (Revis et al. 1990, Ryan et al. 1991, Sin et al. 1989, 1992, Yeoh et al. 1986, 1989). Based on the highest relative absorption value (1/5th), and assuming mercuric chloride is absorbed at 15%, allows one to estimate a 3% oral absorption value for mercuric sulfide (Revis et al. 1990).

Since EPA only has a reference dose for mercuric chloride, it is necessary to estimate an oral absorption value for mercuric sulfide so that it can be related to the more toxic mercuric chloride. Using 3% as the oral absorption value for mercuric sulfide, an ingested dose of this species would be equivalent to 20% (3/15) of an ingested dose of mercuric chloride. Based on the data developed by EMSL-LV (Table 6.1), it was assumed that 90% of the total mercury in soils is HgS and that 10% is $HgCl_2$. Based on this assumption the CDI absorption factor was determined to be 0.28 (3/15 * 90% + 15/15 * 10% = 0.28).

TABLE 7.3: Pathway Specific Chronic Daily Intake Estimates for Mercury							
Type of Exposure/Area of Concern	Land Use	Typical Estimate (ug/kg-day)			High-end Estimate (ug/kg-day)		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child	Adult
Soil Ingestion/Millsites, Dayton	Residential	**	**	0.028	0.841	0.142	0.091
Soil Ingestion/Millsites, Brunswick Canyon	Recreational	**	0.002	**	**	0.004	**
Soil Ingestion/Millsites, Sixmile Canyon	Recreational	**	0.005	**	**	0.133	**
Soil Ingestion/Alluvial Fan	Residential	**	**	0.007	0.210	0.035	0.020
Soil Ingestion/Flood Plain Above Lahontan	Residential	**	**	0.005	0.175	0.030	0.019
Soil Ingestion/Flood Plain Below Lahontan	Residential	**	**	0.017	0.650	0.110	0.070
Inhalation of Airborne and Volatile Mercury/ All areas	Residential	**	**	0.031	0.113	0.050	0.031
Inhalation of Airborne and Volatile Mercury/ All areas	Recreational	**	0.005	**	**	0.005	**
Consumption of Domestic Produce/Dayton (see Table 9.4)	Residential	0.247	**	0.120	0.376	0.179	0.153

1. Child = 1 - 6 years of age.
2. School Age child = 7 - 18 years of age.
3. Refers to subsistent fishing.

TABLE 7.3: Pathway Specific Chronic Daily Intake Estimates for Mercury							
Type of Exposure/Area of Concern	Land Use	Typical Estimate (ug/kg-day)			High-end Estimate (ug/kg-day)		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child[2]	Adult
Consumption of White Bass/Carson River Above Lahontan	Recreational	**	**	1.04	**	**	1.95
	Residential[3]	**	**	**	**	**	5.97
Consumption of White Bass/Carson River Below Lahontan	Recreational	**	**	0.33	**	**	0.62
	Residential	**	**	**	**	**	1.90
Consumption of White Bass/Indian Lakes	Recreational	**	**	0.66	**	**	1.24
	Residential	**	**	**	**	**	3.80
Consumption of Walleye/Lahontan	Recreational	**	**	0.78	**	**	1.46
	Residential	**	**	**	**	**	4.48
Consumption of White Bass/Washoe	Recreational	**	**	0.19	**	**	0.36
	Residential	**	**	**	**	**	1.10
Consumption of Shovelers/Carson Lake	Recreational	**	**	0.429	**	**	0.58
Consumption of Shovelers/Stillwater	Recreational	**	**	0.142	**	**	0.232
Consumption of Mallards/Carson Lake	Recreational	**	**	0.078	**	**	0.168
Consumption of Mallards/Stillwater	Recreational	**	**	0.051	**	**	0.141
Consumption of GW Teal/Carson Lake	Recreational	**	**	0.114	**	**	0.203

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age.
3. Refers to subsistence fishing.

TABLE 7.4: Chronic Daily Intake Estimates for Fruit and Vegetables							
Type of Exposure/Area of Concern	Land Use	Typical Estimate (ug/kg-day)			High-end Estimate (ug/kg-day)		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child	Adult
Consumption of Root Vegetables/Dayton	Residential	0.167	**	0.081	0.270	0.143	0.100
Consumption of Leafy Vegetables/Dayton	Residential	0.007	**	0.004	0.011	0.006	0.005
Consumption of Above Ground Protected Vegetables/Dayton	Residential	0.018	**	0.008	0.022	0.011	0.013
Consumption of Above Ground Exposed Vegetables/Dayton	Residential	0.011	**	0.010	0.029	0.015	0.012
Consumption of Fruit/Dayton	Residential	0.030	**	0.016	0.044	0.05	0.023
Total Intake of Vegetables & Fruit		0.247	**	0.120	0.376	0.189	0.153

1. Child = 1 - 6 years of age.
2. School Age Child = 7 - 18 years of age.

TABLE 7.5: Pathway Specific Chronic Daily Intake Estimates for Arsenic (Non-cancer)							
Type of Exposure/Area of Concern	Land Use	Typical Estimate (ug/kg-day)			High-end Estimate (ug/kg-day)		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child	Adult
Soil Ingestion/Millsites, Dayton	Residential	**	**	0.014	0.440	0.074	0.050
Soil Ingestion/Millsites, Sixmile Canyon	Recreational	**	0.001	**	**	0.031	**
Soil Ingestion/Alluvial Fan & Flood Plain	Residential	**	**	0.005	0.177	0.032	0.019
Soil Ingestion/Lahontan	Recreational	**	0.000	**	**	0.005	**
Inhalation of Airborne Arsenic/All areas	Residential	**	**	0.001	0.002	0.001	0.001
Inahaltion of Airborne Arsenic/All areas	Recreational	**	8.0 E-6	**	**	8.4 E-5	**

1. Child = 1 -6 years of age.
2. School Age Child = 7 - 18 years of age.

TABLE 7.6: Pathway Specific Chronic Daily Intake Estimates for Arsenic (Cancer)							
Type of Exposure/Area of Concern	Land Use	Typical Estimate (ug/kg-day)			High-end Estimate (ug/kg-day)		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child	Adult
Soil Ingestion/Millsites, Dayton	Residential	**	**	0.002	0.037	0.013	0.020
Soil Ingestion/Millsites, Sixmile Canyon	Recreational	**	1.19 E-4	**	**	0.005	**
Soil Ingestion/Alluvial Fan & Flood Plain	Residential	**	**	0.001	0.015	0.005	0.008
Soil Ingestion/Lahontan	Recreational	**	2.16 E-5	**	**	0.001	**
Inhalation of Airborne Arsenic/All areas	Residential	**	**	7.00 E-5	1.74 E-4	1.52 E-4	2.40 E-4
Inhalation of Airborne Arsenic/All areas	Recreational	**	1.38 E-6	**	**	1.44 E-5	**

1. Child = 1 - 6 years of age.
2. School Age Child = 7 - 18 years of age.

Arsenic (As)

Typically, 100% of ingested As is assumed to be bioavailable to the human, based on drinking water studies aimed at soluble forms (ATSDR 1991, WHO 1984). However, based on personal communication between Stan Smucker and Rosanne Lorenzare (1994), an oral absorption factor of 0.8 was used to estimate intake of arsenic with soils.

8.0 TOXICITY ASSESSMENT

This section presents toxicity values that are used to calculate potential risks for the site and discusses the basis for these values and the uncertainty associated with them. The toxicity values are compared and/or combined with the exposure estimates (CDI's) presented in Tables 7.3 through 7.6, to provide quantitative risk estimates.

The toxicity assessment weighs available evidence regarding the potential for particular chemicals to cause adverse effects in exposed individuals (weight-of-evidence), and quantitatively characterizes the relationship between the extent of exposure to an agent and the increased likelihood and/or severity of adverse effects (dose-response assessment). For *mercuric mercury*, the toxicity assessment relies on data gathered from experiments on other mammalian species such as rat, mouse, and hamster. For *methyl mercury, elemental mercury*, and *arsenic*, human epidemiologic studies are available that show a positive correlation between exposure to a chemical and the health effects.

The toxicity assessment evaluates carcinogenic and noncarcinogenic effects of chemicals by different methods. This is based on the assumption that carcinogens and noncarcinogens act by fundamentally different mechanisms. Most regulatory agencies assume that carcinogenic effects can occur at any exposure level. This "no-threshold" assumption has been adopted by regulatory agencies as a conservative practice to protect public health. Noncarcinogenic effects are generally thought to occur only if exposure to a chemical exceeds some "threshold" value.

8.1 TOXICITY ASSESSMENT OF CARCINOGENIC EFFECTS

The current risk assessment practice for carcinogens is based on the assumption that there is no threshold dose below which carcinogenic effects would not occur. Carcinogenic effects of chemicals are evaluated on the basis of two components:

- Qualitative determination of the likelihood of it being a human carcinogen (weight-of-evidence); and

- Quantitative assessment of the relationship between exposure dose and response (cancer slope factor).

Potential adverse effects of carcinogens are evaluated quantitatively based on the probability of contracting cancer. The EPA has derived Cancer Slope Factors (CSFs) for chemicals with possible carcinogenic effects. The CSF is defined as the excess lifetime risk of cancer, per milligram of chemical intake, per kilogram of body weight, per day. Excess lifetime cancer risk is the increment above the current background level which is 1 out 3 people develop cancer within their lifetime.

8.2 TOXICITY ASSESSMENT OF NONCARCINOGENIC EFFECTS

Two types of noncarcinogenic effects are evaluated in the HHRA, chronic effects and acute or short-term effects.

8.2.1 CHRONIC EFFECTS

Reference dose (RfD) or reference concentrations (RfC) values cited in the literature are used as numeric indicators of chronic toxicity (EPA defines chronic toxicity as occurring as the result of seven years or more of exposure). RfDs for chronic exposure are the maximum daily amounts (expressed as milligrams of chemical intake, per kilogram of body weight, per day) which would be allowable without observed adverse health effects (EPA, 1989a). Subchronic and chronic values are obtained from quantitative information available from animal studies or observations made in human epidemiological studies relating intake and noncarcinogenic effects. The highest subchronic or chronic exposure level not causing adverse effects or the no observed adverse effect level (NOAEL) is determined from available studies reported in the literature. The NOAEL is then divided by appropriate uncertainty factors (for extrapolating from high doses to low doses, for extrapolating between species, and for protecting sensitive populations).

8.2.2 SHORT TERM EFFECTS

In some cases, potential exposures and risks due to short-term exposures can be quantitatively assessed; however there is, as yet, no simple or widely accepted method for estimating such risks.

8.3 DOSE-RESPONSE RELATIONSHIPS

In this section, quantitative aspects on dose-response relationships are given, whenever possible. Unfortunately, such data are generally very scanty or nonexistent, and this makes risk evaluation difficult. The EPA derived Reference Doses (RfDs) and Reference Concentrations (RfCs) for mercury and arsenic are described in Table 8.1 and are discussed herein.

8.3.1 MERCURY

In this HHRA, inorganic mercury includes mercury in the form of elemental mercury (Hg^o), mercuric mercury salts (e.g. mercuric sulfide or mercuric chloride), as well as well as those complexes in which mercuric ions can form reversible bonds to sulfhydryl groups in soil. Organic mercury refers to methyl mercury, the dominant species present in fish.

The various forms of mercury vary with respect to toxicity. Methyl mercury is identified as the most toxic form of mercury, targeting the developing nervous system. Mercuric mercury on the other hand targets the kidney, producing an immunotoxic response that may lead to more serious kidney effects. Because elemental mercury readily oxidizes to mercuric mercury and can also cross the blood-brain barrier, it produces both kidney and neurologic effects (high frequency intention tremor and neurobehavioral impairment).

Methyl Mercury

The major source of human exposure to methyl mercury is through the diet, more specifically from the consumption of fish. In most countries including the U.S., the important food fishes have methyl mercury levels in their edible portion not exceeding 0.3 ppm (WHO 1976, 1990). However, levels in such predatory species as ocean tuna, shark, and swordfish often exceed these levels and may contain methyl mercury levels in excess of 1 ppm, the FDA's action limit (EPA 1984a, CDHS 1987, ATSDR 1992).

TABLE 8.1: EPA Derived Reference Doses (RfD) and Reference Concentrations (RfC) for Noncarcinogenic Effects						
Chemical of Concern	**Oral RfD (ug/kg-day)[a]**	**Inhalation RfC (ug/m³)[a]**	**Confidence**	**Uncertainty Factor**	**Source**	**Critical Effect and Species and Studied**
Arsenic	0.3[b] (0.1 - 0.8)	NA[c]	Medium	3	IRIS	Hyperpigmentation, keratosis and possible vascular complications in humans.
Elemental Mercury Hg(0)	NA	0.3	Not Available	30	HEAST	Neurotoxicity in humans.
Inorganic Mercury (Hg^{2+})	0.3	NA	Not Available	1000	HEAST	Inflammation of the kidney in rats.
Organic Mercury (methyl-Hg)	0.3	NA	Medium	10	IRIS	CNS effects in humans.

a.U.S. EPA defines the Rfd or RfC as "an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of daily exposure level for human populations, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime."

b. As noted in IRIS, there are scientific arguments for somewhat higher and somewhat lower RfD values for arsenic, so that a range of values is presented with RfD used in this HHRA.

c. Not applicable or not available

Concerning the risks to children and adults related to methyl mercury, a daily intake of 3-7 ug/kg body weight (which translates to approximately 200 ug/liter in blood) would cause adverse effects on the nervous system, manifested as an approximately 5% increase in the incidence of paresthesia. Based on this relationship between intake and blood levels, an oral RfD of 0.3 ug/kg-day for methyl mercury (organic) was derived by EPA (1993b). An uncertainty factor of 10 was used to derive the RfD for methyl mercury.

The actual exposure level (or body burden) of methylmercury in humans which can lead to subtle changes in an unborn child are largely unknown (WHO 1990, ATSDR 1992). Methylmercury is believed to inhibit the growth of the fetal brain and the migration of neurons from their embryological origin to their final destination. Methyl mercury appears to produce subtle psychological and behavioral effects in newborns exposed in utero, at levels below minimum effect levels in adults (WHO 1990, ATSDR 1992, Stern 1993). It is acknowledged that the RfD for adults may not be protective of an unborn child.

Mercuric Mercury Salts

Most adverse effects related to mercuric salts in humans have been reported after oral ingestion. However, even for this route, only limited information is available as far as dose-effect relationships are concerned and the information is only available for soluble mercuric salts (mercuric chloride) in laboratory animals. Relatively insoluble salts such as the mercuric sulfides are even less well characterized but expected to be less toxic due to a decreased bioavailability (See Section 7.2.4).

Based upon the evaluation in animals, the most sensitive adverse effect for inorganic mercury risk assessment is the formation of mercuric-mercury-induced auto-immune glomerulonephritis. This effect in animal studies is believed to be related to the eventual development of proteinuria in humans, an early indicator of kidney damage. The first step in the mercury-induced disease process is the production and deposition of IgG antibodies to the glomerular basement membrane (ATSDR 1992, WHO 1991, EPA 1993b).

The Brown Norway rat is considered a good test species for the study of mercuric-mercury auto-immune glomerulonephritis (although this effect has also been observed in rabbits). Based on the on studies with the Brown Norway rat, EPA (1993b) has derived an oral RfD for both chronic and subchronic exposures of 0.3 ug/kg-day (Andres 1984, Druet et al. 1978, Bernaudin et al. 1981). An uncertainty factor of 1,000 was used to derived the RfD.

Elemental Mercury Vapor

Over-exposure to elemental mercury typically occurs from inhaling mercury vapors. Sensitive tissue targets of elemental mercury include the brain and kidney. Initial neurological effects include a fine high-frequency intention tremor and neurobehavioral impairment. Peripheral nerve involvement has also been observed (WHO 1976, 1991). An increased prevalence of proteinuria in mercury workers, compared with a control group, and a significant correlation between urinary mercury excretion and protein excretion have also been demonstrated (ATSDR 1992).

WHO (1976) found no evidence of the classical symptoms of mercurialism, erethism, intentional tremor, or gingivitis below a time-weighted occupational exposure to mercury in air of 100 ug/m^3. However, symptoms such as loss of appetite and psychological disturbance may occur at lower exposure levels. These levels have not been precisely defined.

EPA (1993c) has derived an inhalation reference concentration (RfC) for elemental mercury of 0.3 ug/m^3 for both chronic and subchronic exposures based on several human occupational studies in which neurotoxicity was observed (Fawer et al. 1987, Piikivi and Tolonen 1989, Piikivi and Hanninen 1989, Piikivi 1989). An uncertainty factor of 30 was used to derive both inhalation RfCs. The RfD/RfC workgroup has verified RfC, and input of these values into the IRIS database is pending.

8.3.2 ARSENIC

Systemic Effects

Chronic exposure of humans to this trace metal can produce toxic effects on both the peripheral and central nervous systems, keratosis, hyperpigmentation, precancerous dermal lesions, and cardiovascular damage (EPA 1984b, Tseng 1977, ATSDR 1991). Effects may be local and systemic.

Skin effects in form of hyperkeratosis, hyperpigmentation, and depigmentation have been observed in different parts of the world after exposure to drinking-water containing high levels of arsenic, and after treatment with drugs containing inorganic arsenic. Based on limited data, it is estimated that an exposure to approximately 1 mg of arsenic per day for a 70 kilogram person may give rise to skin effects (WHO 1986).

Cardiovascular effects, in the form of electrocardiographic changes and peripheral vascular disorders have been observed in persons exposed to arsenic. Inadequate peripheral circulation is reported to cause gangrene, referred to as "blackfoot disease" by the Taiwanese. Exposure to arsenic from many years, resulting in a total ingested dose of about 20 g arsenic, corresponded to a prevalence of "blackfoot disease" of about 3%.

Peripheral and central nervous system effects have been noted in persons exposed to arsenic. Peripheral neurological damage has been observed in persons consuming arsenic-containing antiasthmatic preparations on a long-term basis. The exposure corresponded to 3-10 mg of arsenic per day in the form of arsenic (III) oxide or arsenic sulfide. Disturbances of the central nervous system function were noted in a follow-up of Japanese infants, fifteen years after exposure to an average daily arsenic dose of about 3.5 mg for one month. The occurrence of severe hearing loss and brain wave abnormalities was indicated. However, the data were considered not to be conclusive (WHO 1986, ATSDR 1991.

Cancer

EPA (1993b) has classified arsenic as a Human Carcinogen (Group A). Epidemiological studies of workers in smelters and in plants manufacturing arsenical pesticides have shown that inhalation of arsenic is strongly associated with lung cancer and perhaps with hepatic angiosarcoma (EPA 1984b). Ingestion of arsenic has been linked to a form of skin cancer and more recently to bladder, liver, and lung cancer (Tseng 1977, Tseng et al. 1968, Chen et al. 1986).

A roughly linear relationship between cumulative arsenic exposure and the lung cancer risk has been demonstrated (Tseng 1977, ATSDR 1991, EPA 1993b). Though data are uncertain, it could be estimated that exposure to airborne arsenic levels of about 50 ug/m3 (probably mostly arsenic (III) oxide) for more than 25 years would result in a nearly 3-fold increase in mortality due to lung cancer over the age of 65 years. Based on these and other findings, EPA has developed an inhalation unit risk of 4×10^{-3} $(ug/m^3)^{-1}$ which is equivalent to a slope factor of 50 $(mg/kg/day)^{-1}$ assuming a 70 kilogram individual inhales 20 m^3/day. An absorption factor of 30% was used to calculate the slope factor from the unit risk (EPA 1993b), and the resulting value is 15 $(mg/kg/day)^{-1}$. The inhalation unit risk is the geometric mean value of unit risks derived from four occupational studies on two different exposure populations (EPA 1984b).

Exposure to inorganic arsenic can cause skin cancer, mainly tumors of low malignancy. This has been observed following ingestion of arsenic-rich drinking-water and the consumption of arsenic-containing drugs. A total dose of several grams has usually been required for the development of cancer. EPA's oral cancer potency factor is based on an epidemiological study in Taiwan which indicated an increased incidence of skin cancer in individuals exposed to arsenic in drinking water (Tseng 1977). EPA (1993b) has derived an oral unit risk of 5×10^{-5} $(ug/L)^{-1}$ for arsenic, which is equivalent to a slope factor of 1.75 $(mg/kg/day)^{-1}$, assuming a 70 kilogram individual ingests 2 liters of water per day.

9.0 RISK CHARACTERIZATION

Risk characterization combines the exposure and toxicity assessments to produce quantitative estimates of risk associated with the chemicals of potential concern. This section presents the estimated health risks for complete exposure pathways, expressed as a hazard quotient (HQ) or hazard index (HI) for noncancer risks and as a probability value for cancer risks. Based on these values and other information, the significance of the risk estimates are explained in this section and the uncertainties associated with the risk estimates are discussed.

Current risks are quantitatively evaluated for the pathways identified in Table 7.2 and future scenarios are discussed. Current risks are quantitatively estimated for each population of potential concern identified in Section 5 using the CDI estimates presented in Section 7. Health risks were quantitatively estimated for the highest exposure that is reasonably expected to occur (high-end estimate) as well as for "typical" exposure. Although the focus of a HHRA are high-end estimates, the defined range was considered in the interpretation of the risk estimates.

9.1 APPROACH TO ESTIMATE HUMAN HEALTH RISKS

Noncarcinogenic and carcinogenic health effects are presented separately because these risks are evaluated differently. The hazard indices are developed by employing a reference dose (RfD) which assumes that no adverse health effects will occur until some threshold level of exposure is exceeded. Carcinogenic risk is estimated by employing a cancer slope factor which assumes that any incremental exposure to a carcinogenic chemical result in an incremental probability of developing cancer.

9.1.1 APPROACH TO ESTIMATE NONCARCINOGENIC RISKS

Estimates of noncarcinogenic risks were calculated by dividing the estimated chemical-specific chronic daily intake (ug/kg-day) by the respective RfD (ug/kg-day). The ratio that results is referred to as a Hazard Quotient (HQ = CDI/RfD). Hazard Quotients were summed for each exposure pathway applicable to each population of potential concern. The HQs for multiple pathways and contaminants are summed to determine a Hazard Index value (HI).

EPA suggests that a HI greater than one (1) indicates that the associated exposure scenario has a potential to result in adverse noncarcinogenic health effects and additional evaluation may be necessary. This potential for adverse health effects increases as the HI value increases. However, the level of concern does not increase linearly becuase RfDs do not have equal accuracy or precision and because RfDs are not based on the same toxic effects. Thus, the slopes of the dose-response curve in excess of the RfD can range widely depending on the substance. Also, a ratio of 0.001 does not mean that there is a one in one thousand chance of the effect occurring.

The calculated HQs for mercury and arsenic are presented in Tables 9.1 and 9.2, respectively.

9.1.2 APPROACH TO ESTIMATE LIFETIME EXCESS CANCER RISKS

EPA uses the linear multistage model for extrapolating cancer risks from relatively high dose levels, where cancer responses can be measured, to relatively low dose levels, which are of concern in the environment. This dose response extrapolation is known as a cancer slope factor (CSF).

To calculate carcinogenic risks due to arsenic, the estimated chronic daily intake for arsenic was multiplied by arsenic's CSF (1.75 $(mg/kg\text{-}day)^{-1}$ for oral exposure and 15 $(mg/kg\text{-}day)^{-1}$ for inhalation). The resulting risk estimate is the incremental probability that an individual will develop cancer from the estimated exposure in their lifetime. Although cancer risks through oral routes are qualitatively different than those associated with inhalation exposures, for the purposes of this HHRA, cancer risks for arsenic were summed across pathways.

Potential carcinogenic risks are compared to acceptable risk ranges established by EPA in the National Contingency Plan (EPA, 1990b) for the purpose of establishing remedial objectives. The carcinogenic risk range is 1×10^{-4} to 1×10^{-6}. The calculated carcinogenic risks for arsenic are presented in Table 9.3.

TABLE 9.1: Pathway Specific Hazard Quotients for Mercury							
Type of Exposure/Area of Concern	Land Use	Typical Estimate			High-end Estimate		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child	Adult
Soil Ingestion/Millsites, Dayton	Residential	**	**	0.09	2.80	0.47	0.30
Soil Ingestion/Millsites, Brunswick Canyon	Recreational	**	0.01	**	**	0.24	**
Soil Ingestion/Millsites, Sixmile Canyon	Recreational	**	0.02	**	**	0.44	**
Soil Ingestion/Alluvial Fan	Residential	**	**	0.02	0.69	0.12	0.07
Soil Ingestion/Flood Plain Above Lahontan	Residential	**	**	0.02	0.58	0.10	0.06
Soil Ingestion/Flood Plain Below Lahontan	Residential	**	**	0.06	2.16	0.37	0.23
Inhalation of Airborne and Volatile Mercury/All areas	Residential	**	**	0.10	0.38	0.17	0.10
Inhalation of Airborne and Volatile Mercury/All areas	Recreational	**	0.002	**	**	0.016	**
Consumption of Domestic Produce/Dayton	Residential	0.82	**	0.40	1.25	0.60	0.51

1. Child = 1 - 6 years of age.
2. School Age child = 7 - 18 years of age.
3. Refers to subsistence fishing.

TABLE 9.1: Pathway Specific Hazard Quotients for Mercury							
Type of Exposure/Area of Concern	Land Use	Typical Estimate			High-end Estimate		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child[2]	Adult
Consumption of White Bass/Carson River Above Lahontan	Recreational	**	**	3.47	**	**	6.50
	Residential[3]	**	**	**	**	**	19.90
Consumption of White Bass/Carson River Below Lahontan	Recreational	**	**	1.10	**	**	2.07
	Residential	**	**	**	**	**	6.30
Consumption of White Bass/Indian Lakes	Recreational	**	**	2.20	**	**	4.13
	Residential	**	**	**	**	**	12.67
Consumption of Walleye/Lahontan	Recreational	**	**	2.60	**	**	4.87
	Residential	**	**	**	**	**	14.93
Consumption of White Bass/Washoe	Recreational	**	**	0.64	**	**	1.20
	Residential	**	**	**	**	**	3.67
Consumption of Shovelers/Carson Lake	Recreational	**	**	1.43	**	**	1.95
Consumption of Shovelers/Stillwater	Recreational	**	**	0.47	**	**	0.77
Consumption of Mallards/Carson Lake	Recreational	**	**	0.26	**	**	0.56
Consumption of Mallards/Stillwater	Recreational	**	**	0.17	**	**	0.47
Consumption of GW Teal/Carson Lake	Recreational	**	**	0.38	**	**	0.68

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age.
3. Refers to subsistence fishing.

TABLE 9.2: Pathway Specific Hazard Quotients for Arsenic (Non-Cancer)							
Type of Exposure/Area of Concern	Land Use	Typical Quotient			High-end Quotient		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child	Adult
Soil Ingestion/Millsites, Dayton	Residential	**	**	0.05	1.23	0.21	0.16
Soil Ingestion/Millsites, Sixmile Canyon	Recreational	**	0.002	**	**	0.10	**
Soil Ingestion/Alluvial Fan & Flood Plain	Residential	**	**	0.02	0.59	0.10	0.06
Soil Ingestion/Lahontan	Recreational	**	0.0004	**	**	0.01	**
Inhalation of Airborne Arsenic/All areas	Residential	**	**	0.002	0.007	0.003	0.002
Inhalation of Airborne Arsenic/All areas	Recreational	**	0.00003	**	**	0.0003	**

1. Child = 1 - 6 years of age.
2. School Age Child = 7 - 18 years of age.

TABLE 9.3: Pathway Specific Cancer Risks for Arsenic							
Type of Exposure/Area of Concern	Land Use	Typical Quotient			High-end Quotient		
		Child[1]	School Age Child[2]	Adult	Child	School Age Child	Adult
Soil Ingestion/Millsites, Dayton	Residential	**	**	3.1 E-6	**	2.2 E-5	3.5 E-5
Soil Ingestion/Millsites, Sixmile Canyon	Recreational	**	2.1 E-7	**	**	9.5 E-6	**
Soil Ingestion/Alluvial Fan	Residential	**	**	1.2 E-6	**	9.0 E-6	1.4 E-5
Soil Ingestion/Lahontan	Recreational	**	3.8 E-8	**	**	1.4 E-6	**
Inhalation of Airborne Arsenic/All areas	Residential	**	**	1.1 E-6	**	2.3 E-6	3.6 E-6
Inhalation of Airborne Arsenic/All areas	Recreational	**	2.1 E-8	**	**	2.2 E-7	**

1. Child = 1 - 6 years of age.
2. School Age Child = 7 - 18 years of age.

9.2 CHARACTERIZATION OF HEALTH RISKS

This section characterizes the health risks associated with mercury and arsenic for the populations of potential concern. Health risks are estimated and evaluated for populations living near historic millsites, on the alluvial fan, and on the flood plain. Health risks are also evaluated for recreation in open land use areas (i.e., Sixmile Canyon). Finally, health risks are estimated and evaluated for people who consume fish and waterfowl from the Carson River system and from Washoe Lake. The HQs used to determine HIs are taken from Tables 9.1 through 9.3. It must be recognized that these HIs are only crude estimates of risk.

9.2.1 NONCARCINOGENIC HEALTH RISKS FOR RESIDENTS LIVING NEAR HISTORIC MILLSITES

Residential exposures near millsites was evaluated using the exposure point concentrations for MS004-SA1. Exposure estimates for this area were considered to represent reasonable maximum exposure. Table 9.4 presents the HIs for this scenario. Since domestic gardens are not common to all residents, the HIs which includes this pathway are broken out and discussed separately.

As is indicated in Table 9.4, the high-end estimate for a child exceeds a HI of 1 ("safe" value) by a factor of 4 without considering potential exposure related to produce consumption. This is mostly due to incidental soil ingestion which represents approximately 90% of the estimated exposure for a child. Given that the HQs for mercury exposure via soil ingestion were derived using data from MS004-SA1, these HIs are most relevant to residents living along River Street across from the Lyon County park. Other areas where similar levels of mercury occur in residential areas are MS001-SA, MS002-SA, MS003-SA, MS004-SA2, and MS030-SA. Although a HI above 1 exceeds the declared "safe" level for trace metals, the results do not necessarily imply that an adverse effect would occur at these levels. For both arsenic and mercury, the RfDs incorporate a margin of safety in the value to be health-protective and to consider the uncertainties implicit in the approach.

Without considering potential exposure related to consumption of produce, the HQs for inhalation of airborne mercury and arsenic represent less than 10% of the HI for a child. Based on these results, the inhalation pathway is not expected to be of concern for residents living on or near impacted areas.

TABLE 9.4: Potential Hazard Indices for Residents Near Millsites					
Type of Exposure/Land Use	**Contaminant**	**Typical Estimate**	**High-end Estimate**		
		Adult	**Child[1]**	**School Age Child[2]**	**Adult**
Soil Ingestion/ Residential	Mercury	0.09	2.80	0.47	0.30
	Arsenic	0.05	1.23	0.21	0.16
Dust and/or Vapor Inhalation/Residential	Mercury	0.10	0.38	0.17	0.10
	Arsenic	0.00	0.01	0.00	0.00
Hazard Index		0.24	4.42	0.85	0.56
Produce Consumption/ Residential	Mercury	0.40	0.82	0.60	0.51
Hazard Index w/Produce Consumption		0.64	5.24	1.45	1.07

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age

Table 9.4 also presents HI estimates which include the HQs for consumption of domestic produce. These HIs are relevant to the small percentage of residences on or near impacted areas with vegetable gardens and fruit trees (see Figure 17). According to these results, produce consumption could be a relatively significant exposure pathway. However, these results should be interpreted with caution given the uncertainty and conservative assumptions which may overestimate exposure via this pathway. First, the data set for fruit and vegetables was small and the number of root vegetables (i.e., carrots, beats, and radishes), which contribute the greatest to the HQ for this pathway (see Table 7.4), were limited to four samples. Also, the HQs presented in Table 9.4 assumes that 25% of the total dietary intake of fruit and vegetables is from a domestic garden in an impacted area. Exposure to arsenic via this pathway was not evaluated because fruit and vegetables were not analyzed for arsenic.

In addition to the exposure pathways included in Table 9.4, potential exposure pathways for mercury and arsenic include incidental soil ingestion and inhalation of airborne contaminants during recreational activities in such areas as Sixmile Canyon, Brunswick Canyon, Rock Point Mill, and Lahontan Reservoir beach areas. Presented in Table 9.5, are the estimated HIs which include the HQs derived for exposure associated with recreation activities in Sixmile Canyon. Among the areas

TABLE 9.5: Potential Cumulative Hazard Indices with Recreational Land Use					
Type of Exposure/Land Use	**Contaminant**	**Typical Estimate**	**High-end Estimate**		
		Adult	**Child[1]**	**School Age Child[2]**	**Adult**
Soil Ingestion/ Recreational	Mercury	**	**	0.31	**
	Arsenic	**	**	0.03	**
Dust and/or Vapor Inhalation/Recreational	Mercury	**	**	0.0042	**
	Arsenic	**	**	0.003	**
Residential Land Use Hazard Index		0.24	4.4	0.85	0.56
Residential and Recreational Land Use Hazard Index		0.24	4.4	1.20	0.56

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age

mentioned, the highest levels of both mercury and arsenic were detected in Sixmile Canyon. Using the HQs derived for a school age child, the HI is estimated to be slightly greater than one. Approximately 30% of this exposure would be related to recreational land use. Based on these estimates, contamination in open land areas is not expected to pose significant health risks with the current land use. Exposure would be significant if land use were to become residential.

9.2.2 CARCINOGENIC HEALTH RISKS FOR RESIDENTS LIVING NEAR HISTORIC MILLSITES

Carcinogenic risks for residents in Dayton were estimated using arsenic data from the MS002 sample area. The estimated cancer risks levels are described in Table 9.6. As indicated in Table 9.6, the potential lifetime cancer risks levels are estimated to be within the acceptable range cited in the National Contingency Plan (EPA, 1990b).

TABLE 9.6: Potential Carcinogenic Risks for Residents Near Millsites					
Type of Exposure/Land Use	Contaminant	Typical Estimate	High-end Estimate		
		Adult	Child[1]	School Age Child[2]	Adult
Soil Ingestion /Residential	Arsenic	3.1 E-6	**	2.2 E-5	3.5 E-5
Dust and/or Vapor Inhalation/Residential	Arsenic	1.1 E-6	**	2.3 E-6	3.6 E-6
Soil Ingestion /Recreational	Arsenic	**	**	9.5 E-6	**
Dust Inhalation/Recreational	Arsenic	**	**	2.2 E-7	**
Carcinogenic Risk		3 E-6	**	3 E-5	4 E-5

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age

9.2.3 NONCARCINOGENIC HEALTH RISKS FOR RESIDENTS LIVING ON THE ALLUVIAL FAN

Residents living in Mark Twain were selected as the population with highest exposure to mercury and arsenic deposited on the alluvial fan. Table 9.7 presents a range of potential HIs for residents on the alluvial fan. The HQs for consumption of domestic produce are included in Table 9.7 to describe the potential risks if this was also an exposure pathway for mercury.

It is important to note that the exposure point concentration used to estimate chronic daily intake of mercury by soil ingestion was derived using the entire data set for the alluvial fan (n = 27). Thus, the HIs presented in Table 9.7 only indicate that there are levels of mercury in surface soil which would translate into a HI greater than 1 for children. According to the data developed as part of this remedial investigation and remote sensing data (Fenstermaker, 1992), elevated levels of mercury generally occur in areas of surface transport where tailings from Sixmile Canyon are deposited. Current residential areas on the alluvial fan are not near these areas and thus, do not appear to be impacted by mercury or the other COPCs. The risk estimates provided in Table 9.7 would be relevant if the areas of surface transport were used for residential development.

TABLE 9.7: Potential Hazard Indices for Residents on the Alluvial Fan						
Type of Exposure/Land Use	**Contaminant**	**Typical Estimate**	**High-end Estimate**			
		Adult	**Child[1]**	**School Age Child[2]**	**Adult**	
Soil Ingestion/ Residential	Mercury	0.02	0.69	0.12	0.07	
	Arsenic	0.02	0.59	0.10	0.06	
Dust and/or Vapor Inhalation/Residential	Mercury	0.10	0.38	0.17	0.10	
	Arsenic	0.00	0.01	0.00	0.00	
Hazard Index		0.14	1.67	0.39	0.23	
Produce Consumption/ Residential	Mercury	0.40	0.82	0.60	0.51	
Hazard Index w/Produce Consumption		0.54	2.49	0.99	0.74	

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age

Potential long-term health risks associated with inhalation of mercury and arsenic are not expected to contribute significantly to the overall HI value for residents on the alluvial fan. Also, since current residential areas do not appear to be impacted by mercury, consumption of produce is not expected to be a pathway of concern for residents on the alluvial fan.

9.2.4 CARCINOGENIC HEALTH RISKS FOR RESIDENTS ON THE ALLUVIAL FAN

The potential carcinogenic risks associated with arsenic are described in Table 9.8 for residents on the alluvial fan. Based on the arsenic levels measured on the alluvial fan, the potential lifetime cancer risks values for residents of Mark Twain are estimated to be within the acceptable risk range cited in the National Contingency Plan (EPA, 1990b).

TABLE 9.8: Potential Carcinogenic Risks for Residents on the Alluvial Fan					
Type of Exposure/Land Use	Contaminant	Typical Estimate	High-end Estimate		
		Adult	Child[1]	School Age Child[2]	Adult
Soil Ingestion /Residential	Arsenic	1.2 E-6	**	9.0 E-5	1.4 E-5
Dust and/or Vapor Inhalation/Residential	Arsenic	1.1 E-6	**	2.3 E-6	3.6 E-6
Soil Ingestion /Recreational	Arsenic	**	**	9.5 E-6	**
Dust Inhalation/Recreational	Arsenic	**	**	2.2 E-7	**
Carcinogenic Risk		2 E-6	**	1 E-4	2 E-5

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age

9.2.5 NONCARCINOGENIC HEALTH RISKS FOR RESIDENTS LIVING ON THE FLOOD PLAIN

The Carson River flood plain is considered to be a significant sink for mill tailings. However, due to the large surface area of the flood plain and the dynamic nature of the flood plain, it is difficult to define the distribution of mercury in the flood plain, and thus, to assess human exposure. In order to evaluate potential health risks for residents on the flood plain, data from an impacted area on the flood plain was used to derive exposure point concentrations and these exposure point concentrations were used to evaluate residential land use. This area, FA010, includes the highest mercury levels measured on the flood plain. The HIs for residential exposures are presented in Table 9.9. Again, the HQs for consumption of domestic produce are included in Table 9.9 to describe the relative significance of this pathway.

TABLE 9.9: Potential Hazard Indices for Residents on the Carson River Flood Plain					
Type of Exposure/Land Use	**Contaminant**	**Typical Estimate**	**High-end Estimate**		
		Adult	**Child[1]**	**School Age Child[2]**	**Adult**
Soil Ingestion/ Residential	Mercury	0.06	2.16	0.37	0.23
	Arsenic	0.02	0.59	0.10	0.06
Dust and/or Vapor Inhalation/Residential	Mercury	0.10	0.38	0.17	0.10
	Arsenic	0.00	0.01	0.00	0.00
Hazard Index		0.18	3.14	0.64	0.39
Produce Consumption/ Residential	Mercury	0.40	0.82	0.60	0.51
Hazard Index w/Produce Consumption		0.58	3.96	1.24	0.90

1. Child = 1 - 6 years of age.
2. School age child = 7 - 18 years of age

As with the HIs estimated for the alluvial fan, these estimates only indicate that there are mercury levels on the flood plain which translate into a HI greater than 1 for a child. Among the 20 areas sampled on the flood plain, there was only one other area (FP003) where concentrations exceeding 80 mg/kg were detected in surface soil. Therefore, the HIs presented in Table 9.10 are likely a "worst case" and should be interpreted with caution.

9.2.6 CARCINOGENIC HEALTH RISKS FOR RESIDENTS LIVING ON THE FLOOD PLAIN

The potential carcinogenic risks for residents living on the flood plain are the same as the risks levels estimated for residents living on the alluvial fan (see Table 9.8). As for residents living on the alluvial fan, the potential lifetime cancer risks are estimated to be within the acceptable risk range cited in the National Contingency Plan (EPA, 1990b). This does not include cancer risks associated with ingestion of ground water in the Fallon area.

9.2.7 NONCARCINOGENIC HEALTH RISKS FOR INDIVIDUALS WHO CONSUME FISH FROM THE CARSON RIVER SYSTEM AND WASHOE LAKE

Presented in Table 9.10 are a range of HIs for different fisheries affected by mercury. Hazard indices are only described for an adult receptor because food consumption is assumed to be proportional to body weight, so a school age child is expected to have the same level of exposure as an adult. Moreover, a young child is not included as a receptor because there is currently an ongoing debate as to whether the RfD for methyl mercury is sufficiently health protective for unborn or young children in critical stages of development (WHO, 1990, ATSDR, 1992, Stern, 1993). Because fish from the Carson River system are contaminated with mercury, it is recommended that pregnant or nursing mother and young children (< 6 years) not consume fish from these areas.

The HIs presented in Table 9.10 were derived using the RfD for methyl mercury. The RfD for methyl mercury (0.3 ug/kg-day) is based on a predicted "safe" blood level of 200 ug/l mercury. Using the HIs presented in Table 9.10, consumption of fish caught from the Carson River above Lahontan Reservoir is predicted to pose the highest risk, followed by Lahontan Reservoir, Indian Lakes, and Washoe Lake. Evaluating each of the fisheries using an indicator species is considered a conservative approach and it should assure that these HIs are not underestimated. For all of the indicator species, exposure point concentrations were derived from mercury levels in muscle tissue. Therefore, the HIs presented in Table 9.10 may underestimate the risks associated with consuming other parts of the fish.

Included in Table 9.10 are HIs for subsistence fishing. Although there is no documented evidence of subsistence fishing from the Carson River system or Washoe Lake, the water bodies are large enough to support subsistence fishing. Thus, these values are included as a high-end estimate and to demonstrate the significance of this exposure, should it exist.

TABLE 9.10: Potential Hazard Indices for Consumption of Fish from the Carson River System			
Fishery/Indicator Species	Land Use	Typical Estimate	High-end Estimate
		Adult	Adult
Carson River Above Lahontan/White Bass	Recreation	3.47	6.50
	Subsistence[1]	**	19.90
Lahontan Reservoir/ Walleye	Recreation	2.60	4.87
	Subsistence	**	14.93
Carson River Below Lahontan/White Bass	Recreation	1.10	2.07
	Subsistence	**	6.30
Indian Lakes/White Bass	Recreation	2.20	4.13
	Subsistence	**	12.67
Washoe Lake/White Bass	Recreation	0.64	1.20
	Subsistence	**	3.67

9.2.8 NONCARCINOGENIC HEALTH RISKS FOR INDIVIDUALS WHO CONSUME WATERFOWL FROM THE CARSON LAKE AND STILLWATER AREAS

Presented in Table 9.11 are a range of HIs for shovelers and mallards from Carson Lake and Stillwater. With exception for shovelers from the Carson lake area, the level of exposure associated

TABLE 9.11: Potential Hazard Indices for Individuals Who Consumption of Waterfowl from the Carson Lake and Stillwater Areas			
Area/Waterfowl Species	Land Use	Typical Estimate	High-end Estimate
		Adult	Adult
Carson Lake/Shovelers	Recreation	1.43	1.95
Carson Lake/Mallards	Recreation	0.26	0.56
Stillwater/Shovelers	Recreation	0.47	0.77
Stillwater/Mallards	Recreation	0.17	0.47

with consuming the average number of birds bagged during a hunting season does not translate into a HI greater than one. As with fish, the HIs presented in Table 9.13 were determined for the specified indicator species. Given that shovelers generally have higher body burdens than mallards (Table B.19), the HIs presented for shovelers from Carson Lake and Stillwater may overestimate the risk. Also, the consumption rate was estimated assuming that 50% of the total body mass is edible which is also a conservative estimate. However, because the exposure point concentration were derived from muscle tissue samples, the HIs presented in Table 9.13 may underestimate the risks associated with consuming organs (i.e., liver).

Because waterfowl from Carson Lake and Stillwater areas are contaminated with mercury, it is recommended that pregnant or nursing mothers and young children (< 6 years) not consume waterfowl from these areas.

9.2.9 NONCARCINOGENIC RISKS FOR INDIVIDUALS WHO CONSUME TULE BULBS FROM CARSON LAKE

Although this pathway was not quantitatively evaluated, a typical and high-end exposure point concentration was derived based on data developed by Hoffman et. al., 1990. Using the high-end intake parameters for consumption of root vegetables (Table E.4) and the high-end exposure point concentration for tule bulbs (0.32 mg/kg wet wt.), estimated chronic daily intake of tule bulbs would be comparable to the high-end chronic daily intake estimate for root vegetables presented in Table 7.4. Based on these intake parameters, the high-end HI for a child would not exceed one.

9.3 CHARACTERIZATION OF FUTURE RISKS

There is currently insufficient information for evaluating all possible scenarios associated with future land use at the different areas of potential concern. For this HHRA, assumptions of residential use are considered health-protective and consistent with evaluating the site in terms of its maximum beneficial use. Alternative land use of various areas, based on long-term planning, proposed zoning changes by the counties, and Agency and community expectations, should be evaluated for developing realistic estimates of future exposures.

9.4 RISK UNCERTAINTY

It must be recognized that the assessment of noncancer risks and cancer risks by available (generally indirect) methods can provide only crude estimates of risk and this should be borne in mind in making regulatory decisions about permissible exposure concentrations in environmental media.

Site specific uncertainties which were identified for the different exposure scenarios are summarized in Table 9.12 and non-site specific uncertainties are summarized in Table 9.15.

10.0 POTENTIAL LEAD EXPOSURE

The EPA withdrew the established RfD for lead in 1989. This was done primarily because of the absence of a discernible threshold for health effects of lead, the numerous environmental sources of lead, and the complex relationship among multiple lead exposure pathways. However, it has been determined by EPA (EPA 1991a) that blood lead levels appear to provide a useful index of health risks since toxic and other physiological effects can be correlated with blood lead levels. As a result, a blood lead "level of concern" of 10 ug/dL has been identified. This is the blood lead level at which exposure-effect relationship were observed in some studies.

The EPA Lead Uptake/Biokinetic Model, Version 0.5 (UBK model, EPA 1991b) was designed to estimate blood lead levels in children 0 to 6 years of age, based on multi-media lead exposures. The model accounts for the potential environmental and maternal sources of lead (air, diet, drinking water, dust, soil, and the lead concentration in the mother's blood during gestation). The model relies on numerous fundamental assumptions regarding exposure factors, lead absorption, and metabolic physiological interactions among the different body compartments that store or process lead (bone, blood, liver, kidneys, gastrointestinal tract, and urine). The UBK model is used in this analysis to make preliminary estimates of blood lead levels that might result from exposure to lead in residential soils.

Health effects associated with lead are of greatest concern in children because developmental effects are seen at lower blood levels in children than other effects are observed in adults. The same lead intake has greater potential detrimental effects in children than in adults because of the child's lower body weight, lower blood volume, greater absorption of lead in the gut (an estimate 40 to 50 percent in infants compared to about 10 percent in adults), and the apparent greater physiological sensitivity of child development to lead. For these reasons, health risks of lead exposure are commonly addressed only in children. The UBK model does not address effects of lead intake in adults except as the mother's blood lead levels affect the infant. Environmental lead levels that are protective of children are assumed also to be protective of adults.

TABLE 9.12: Summary of Site Specific Uncertainties Associated with Risk Estimates		
Uncertainty Factor	**Effect of Uncertainty**	**Comment**
Exposure point concentrations used for volatile mercury.	May over- or underestimate risk	Exposure point concentrations used for volatile mercury were derived from the method detection limit and were not actually measured. Therefore, levels of volatile mercury in indoor and ambient air may actually be more or less than the exposure point concentration.
Exposure point concentrations for mercury levels in surface soil on the alluvial fan.	May overestimate risk	Exposure point concentrations used to evaluate incidental ingestion of soil on the alluvial fan were derived from a data set which included samples from the area of transport where tailings from Sixmile Canyon are deposited. Current residential areas on the alluvial fan are north of the area of transport. Mercury levels measured in samples collected from current residential areas did not exceed 25 mg/kg.
Exposure point concentrations for mercury levels in surface soil on the flood plain.	May overestimate risk	Exposure point concentrations used to evaluate incidental ingestion of soil on the flood plain were derived from the highest concentrations detected on the flood plain. The 95 UCL for all of the samples collected from the flood plain (18.20 mg/kg) is a factor of 20 less than the value used to estimate the high-end risks for this scenario.
Use of an indicator species to estimate mercury exposure associated with consumption of fish and waterfowl.	May overestimate risk	To the extent that the actual diets include lesser contaminated fish and waterfowl, the indicator species approach used in this HHRA is likely to overestimate exposures.
Arsenic which was identified in tailings and at historic millsites was not measured in fruit and vegetables.	May underestimate risk	Arsenic can also be taken up by plants.

TABLE 9.13: Summary of Non-Site Specific Uncertainties Associated with Risk Estimates		
Uncertainty Factor	**Effect of Uncertainty**	**Comment**
Cancer slope factors for arsenic	May overestimate risks	Slope factors are based on a 95th percent UCL derived from a linearized model. Considered unlikely to underestimate risks.
Cancer risk estimates assume there is no threshold.	May overestimate risks	Possibility that some threshold exists.
Reference doses (RfDs) for mercuric mercury are derived from animal studies.	May over- or underestimate risks	Extrapolation from an animal to human may induce error because of differences in absorption, pharmacokinetics, target organs, enzymes, and population variability.

10.1 PERSPECTIVES ON THE EPA BLOOD "LEVEL OF CONCERN"

In several studies, blood lead levels as low as 10 to 15 ug/dL have been associated with measurable physiological effects, including interference with heme biosynthetic enzymes, altered vitamin D and pyrimidine metabolism, neurobehavioral deficits in psychomotor and cognitive functions, and reduced growth rate. These effects may be reversible. Analysis of prospective epidemiological studies (Volpe et al. 1991) reveals inconsistencies in the onset, stability, and nature of the neurobehavioral effects correlated with different indices of lead exposure. While technical experts disagree about the biological significance of some of these effects, EPA's interpretation of the evidence is that in infants and children, blood lead levels greater than 10 ug/dL are of concern.

10.2 LEAD EXPOSURE ASSUMPTIONS

The UBK model has conservative default values for all intake and uptake parameters; many of these values can be modified by the user. The model parameters include exposure factors (such as soil and water ingestion rates, soil-to-house dust conversion factors, and dietary lead intake), lead concentrations in environmental media, and pharmacokinetic parameters (such as absorption and excretion rates and body organ partition coefficients). Two exposure factors that cannot be modified by the user and that are very important in determining lead intake include exposure frequency (days/year) and the fraction of soil to which a child is exposed that is contaminated. In addition, the basic algorithms in the model cannot be modified by the user. These algorithms are used to calculate lead intake from the media, lead uptake using absorption coefficients, partitioning among body tissues, and ultimately blood lead levels.

Soil Concentration and Ingestion Rate

The arithmetic mean soil lead concentration for surface soils in Dayton is 129.5 ppm and the 95 UCL is 298.7 ppm. The range of lead concentrations from surface soils in Dayton ranged from 5.2 ppm to 566 ppm. For this evaluation, the 95 UCL was used in evaluating the potential health impacts from child exposure to lead for the Dayton area.

The EPA default soil/dust ingestion rate of 100 mg/day was used as an estimate of soil/dust intake for children. Variability in soil ingestion and other intake parameters is accounted for in the UBK model by the use of a geometric standard deviation (GSD) for the distribution of blood lead levels, which is based on GSDs that are derived from blood lead studies in human populations. The GSD is used to develop probability density functions for distributions of the predicted blood lead levels in populations. Since the GSD describes variability in the blood lead levels, it also accounts for variability in soil intake as well as other parameters. It is also assumed in this analysis that all of the soil ingested by the child is from contaminated source; this is a conservative assumption. The default value of 45 percent/55 percent was used (45 percent of soil is assumed to come from outdoor soil and 55 percent from indoor dust).

Indoor Dust Lead Concentrations

The UBK model permits the user either to specify an indoor dust lead concentration based on site-specific data or to model the dust lead concentrations (multiple source analysis). It was conservatively assumed that the house dust lead concentrations were equal to the outdoor soil concentrations.

Tap Water Lead Concentrations

Site-specific information on lead concentrations in tab was used . Lead was largely undetected in tap water samples, however 2 out of 27 samples did detect levels of potential significance (i.e. 14 and 15 ug/L). To be protective, the highest tap water concentration was assumed in the analysis.

Outdoor Air Lead Concentrations

No site-specific information on outdoor air lead concentrations is currently available for Dayton. Therefore, the EPA UBK default value of 0.20 ug/m^3 was used in the evaluation.

Gastrointestinal Absorption

The rate of lead absorption in human infants, which EPA assumes to be 50 percent for lead from water and food and 30 percent for lead from soil, is used in the model for children age 0 to 6 years. This is a conservative assumption, since absorption rates decrease as a child gets older and approach 10 percent in the adult. The UBK model provides two ways to calculate gastrointestinal absorption: a linear, passive model (which assumes that lead absorption is purely a passive physicochemical process, not facilitated by any biological or physiological mechanisms) and a nonlinear, active-passive model (which assumes that part of the lead uptake is passive while the other part is mediated by a transport system, which is saturable). The nonlinear, active-passive model of gastrointestinal absorption was selected for this analysis, as recommended by the EPA (EPA 1991b).

Other Parameters

EPA default UBK model parameters were used for all other input values. The default values used include those for bioavailability (30 percent from soil/dust and 50 percent from food and water), maternal blood lead concentration (7.5 ug/dL), dietary intake (2.94 to 3.74 ug/day), and lead from paint (zero). It is noted that the UBK model does not allow a paint lead concentration to be input directly.

10.3 RESULTS AND CONCLUSIONS

The results of the EPA UBK model run for the Dayton area, assuming a residential scenario and that the 95 UCL concentration was to be present in residential yards, demonstrate that the levels in soils should not pose a significant health threat to children, even when considering exposures to lead through multiple sources (including diet, tap water, air, and maternal contribution). The UBK print out of the input parameters are presented in Appendix F and the results are given in Table 10.1. The probability of blood lead concentration, averaged over the time of 0 to 72 months of age are shown in Figure 29. The average blood lead concentration was 4.78 ug/dL. The blood lead concentration that is accepted as having no harmful effects to children is 10.0 ug/dL. The percentage of children that would potentially have a blood lead level greater than 10.0 ug/dL with the site-specific exposures at Dayton site would be less than two (i.e. 1.6). The EPA-accepted percentage of children having a blood lead concentration greater than 10.0 ug/dL is five percent. Based on the data, it is concluded that there are no potential adverse health impacts due to exposure to lead in environmental media in the Dayton community.

TABLE 10.1: Calculated Blood Lead and Lead Uptakes for Children							
Age (years)	Blood Level ug/dL	Total Uptake (ug/day)	Soil & Dust Uptake (ug/day)	Diet Uptake (ug/day)	Water Uptake (ug/day)	Paint Uptake (ug/day)	Air Uptake (ug/day)
0.5 - 1	4.47	13.44	8.96	2.94	1.50	0.00	0.04
1 - 2	4.51	15.74	8.96	2.96	3.75	0.00	0.07
2 - 3	4.61	16.38	8.96	3.40	3.90	0.00	0.12
3 - 4	4.72	16.35	8.96	3.29	3.97	0.00	0.13
4 - 5	4.90	16.40	8.96	3.18	4.13	0.00	0.13
5 - 6	4.95	16.87	8.96	3.38	4.35	0.00	0.19
6 - 7	4.99	17.31	8.96	3.74	4.42	0.00	0.19

11.0 CONCLUSIONS

The conclusions of the HHRA are as follows:

- The contaminants of potential concern (COPCs) for the Carson River Mercury Site (CRMS) are *mercury, arsenic* and *lead*. Mercury was imported to the region during the Comstock era (1859 - 1900) to process ore. Although mercury is also naturally occurring in the region, such sources are not considered important relative to the large amount of mercury imported to the region during the Comstock era. Arsenic and lead are naturally occurring trace metals in the region which were concentrated in the environment by natural and anthropogenic processes.

- The highest concentrations of the COPCs are found at and around historic millsites and extant tailing piles. The COPCs also occur in areas where discharged tailings and other eroded material from historic millsites have come to be deposited. These areas include: the alluvial fan below Sixmile Canyon, the flood plain of the Carson River below New Empire, the active channel of the Carson River below New Empire, and bottom sediments in Lahontan Reservoir, Carson Lake, Stillwater Management Area, Indian Lakes and Washoe Lake.

- Although the soil ingestion pathway is important for all of the COPCs, the significance of this pathway varies according to the land use (i.e., residential, occupational and recreational) and according to the concentration of the COPC in surface soil. For residential land use, mercury and arsenic were detected in surface soil at levels which translate into a HI>1 for a young child (< 6 years of age). For recreational or open land use areas (i.e., Brunswick, Sixmile Canyon, Gold Canyon, Lahontan Reservoir, Indian Lakes, and Washoe Lake beach areas), none of the COPCs appear to pose significant risks via this exposure pathway.

- Inhalation of airborne contaminants does not appear to be an exposure pathway of concern for any of the COPCs irrespective of the land use scenario (HI<1).

- Ingestion of ground water does not appear to be an exposure pathway of concern for any of the COPCs.

- Incidental ingestion of surface water and sediment while swimming does not appear to be an

- Incidental ingestion of surface water and sediment while swimming does not appear to be an exposure pathway of concern for any of the COPCs.

- Consumption of produce grown in contaminated soil was found to be a complete exposure pathway for mercury. However, this pathway does not appear to be of concern (HI<1).

- Individuals who consume fish or waterfowl from the Carson River system should be cautioned that the risks are proportional to the amount and type of fish and waterfowl consumed. Using an indicator species approach, typical HI estimates for selected indicator species were found to exceed 1 for the consumption of white bass from the Carson River above and below Lahontan Reservoir, and Indian Lakes; and for the consumption of walleye from Lahontan Reservoir. Also using an indicator species approach, typical HI estimates were found to exceed 1 for the consumption of shovelers from the Carson Lake area. Note, by using an indicator species approach, these HIs may be well overestimated. However, because fish and waterfowl from the Carson River system are contaminated with mercury, it is recommended that pregnant or nursing mothers and young children (< 6 years) not consume fish and waterfowl from these areas.

- Incidental ingestion of surface water and sediment while wading or swimming in Washoe Lake, the Carson River above and below Lahontan Reservoir, and Lahontan Reservoir does not appear

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APENDIX A

TABLE A.1: Comstock Mills				
ID #[1]	Mill Name	General Location	Period of Operation	Capacity (tons/day)[2]
1	Keller and Co.	Dayton	1860 - 1866	20
2	Solomon and Davis	Dayton	1862 - 1871	unknown
3	Sutro	Dayton	1863 - unknown	10
4	Mineral Rapids	Dayton	1861 - unknown	20
5	Birdsall	Dayton	1865 - 1880's	300
6	French's	Dayton	1850's - unknown	unknown
7	Kustel and Winters	Dayton	1859 - 1868	20
8	Rock Point	Dayton	1861 - 1900	112
9	Illinois	Dayton	1863 - 1870's	20
10	Freeborn and Sheldon	Dayton	1863 - unknown	30
11	Succor	Dayton	1862 - 1863	20
12	Gautier	Dayton	1861 - unknown	15
13	Ophir[3]	Dayton	1859 - 1870's	48
14	Kelsey	Silver City	early 1860's - unknown	30
15	Golden Age	Silver City	unknown	10
16	Devil's Gate	Silver City	1860 - unknown	20
17	Bacon and Trench	Silver City	1860 - 1883	40
18	McTigue	Silver City	unknown	20

1. Number refers to the location of the mill on Figure 3.
2. Refers to the maximum crushing capacity reported during the operation of the mill.
3. Refers to both the Ophir and New Ophir mills also know collectively as the Woodworth mills.

TABLE A.1 cont'd: Comstock Mills				
ID #[1]	Mill Name	General Location	Period of Operation	Capacity (tons/day)[2]
19	Phoenix	Silver City	1860 - unknown	22
20	Higgins[3]	Silver City	early 1900's - unknown	unknown
21	Eastern Slope	Silver City	1862 - unknown	20
22	Hope	Silver City	1860's - unknown	20
23	Silver City	Silver City	1861 - unknown	10
24	Union	Silver City	1861 - unknown	15
25	Eagle	Silver City	1864 - unknown	15
26	Trimble	Silver City	1900 - 1930's	10 - 15
27	Pioneer	Silver City	early 1860's - unknown	20
28	Sherman	Silver City	early 1860's - late 1870's	4
29	Bartola	Silver City	early 1860's - unknown	10
30	McDonald	Gold Canyon	1860's - unknown	unknown
31	Barrys	Gold Canyon	early 1860's - unknown	unknown
32	Daney	Gold Canyon	1863 - early 1870's	30
33	Swansea[4]	Gold Canyon	1862 - late 1870's	25
34	Excelsior	Gold Canyon	early 1860's - 1880's	10

1. Number refers to the location of the mill on Figure 3.
2. Refers to the maximum crushing capacity reported during the operation of the mill.
3. The Higgins mill constructed between 1900 and 1920 and was likely a cyanide mill.
4. Also was known as the Humphreys mill.

TABLE A.1 cont'd: Comstock Mills				
ID #[1]	Mill Name	General Location	Period of Operation	Capacity (tons/day)[2]
35	Atlanta	Gold Canyon	1869 - 1880's	30
36	Sacramento	Gold Canyon	1862 - early 1870's	25
37	Frenches[3]	Gold Canyon	1860 - unknown	30
38	Briggs	Gold Canyon	unknown	unknown
39	Mexican	Carson River	1861 - 1880's	120
40	Meade	Carson River	1861 - unknown	20
41	Copper Canyon	Carson River	1862 - unknown	15
42	Morgan	Carson River	1865 - late 1890's	80
43	Brunswick	Carson River	1864 - late 1880's	150
44	Merrimac	Carson River	1866 - 1890	45
45	Santiago	Carson River	early 1860's - 1880's	80
46	Eureka	Carson River	1861 - early 1890's	200
47	Vivian	Carson River	1863 - 1890's	30
48	San Francisco	Carson River	early 1860's - unknown	20
49	Franklin	Carson River	early 1860's - unknown	20
50	Atlantic	Carson River	unknown	3
51	Island	Carson River	early 1860's - unknown	20
52	California Pan	Virginia City	1875 - 1890	360

1. Number refers to the location of the mill on Figure 3.
2. Refers to the maximum crushing capacity reported during the operation of the mill.
3. This mill was originally named the Sparrow & Trench mill.

TABLE A.1 cont'd: Comstock Mills				
ID #[1]	Mill Name	General Location	Period of Operation	Capacity (tons/day)[2]
53	Nevada	Virginia City	1887 - unknown	150
54	Mexican	Virginia City	early 1860's - unknown	10 -15
55	Hoosier State	Virginia City	1862 - unknown	12
56	California Battery	Virginia City	1875 - 1890	100 - 150
57	Sanborn	Virginia City	1870 - unknown	unknown
58	Gould and Carvill[3]	Virginia City	1861 - unknown	12
59	Kendall	Virginia City	unknown	unknown
60	Central Quartz	Virginia City	1860 - unknown	12
61	Consolidated Virginia	Virginia City	unknown	unknown
62	Arizona Comstock	Virginia City	1900's	cyanide mill
63	Sacramento	Virginia City	early 1860's - 1970's	25
64	Mariposa	Virginia City	early 1860's - unknown	30
65	Evans	Virginia City	late 1860's - unknown	13
66	Sierra[4]	Virginia City	unknown	50
67	Land's	Virginia City	late 1860's - unknown	30
68	Bassett[5]	Virginia City	1861 - unknown	18
69	Winfield	Virginia City	early 1860's - unknown	50

1. Number refers to the location of the mill on Figure 3.
2. Refers to the maximum crushing capacity reported during the operation of the mill.
3. The Summit Mill was also at this location.
4. Also was known as the *Sierra Nevada Mill*.
5. Also was known as the Suncook Mill and the Atlantic Mill.

TABLE A.1 cont'd: Comstock Mills				
ID #[1]	Mill Name	General Location	Period of Operation	Capacity (tons/day)[2]
70	Ogden	Virginia City	1860 - unknown	20
71	Empire	Virginia City	late 1880's - unknown	100
72	Atlas	Gold Hill	1862 - unknown	45
73	Piute	Gold Hill	1864 - 1870's	50
74	Papoose	Gold Hill	mid 1860's - unknown	14
75	Pacific	Gold Hill	1864 - unknown	70
76	Ramsdale	Gold Hill	1870 - unknown	5
77	Succor	Gold Hill	early 1860's - early 1870's	25
78	Occidental (New and Old)	Gold Hill	1870 - unknown	50
79	Woodville	Gold Hill	early 1870's - unknown	30
80	Rigby	American Flat	1862 - 1870	14
81	Baltimore	American Flat	1862 - late 1880's	unknown
82	Bay State	American Flat	early 1860's - 1871	35
83	Reed and Wade's Quartz	American Flat	1861 - 1864	8
84	American Flat	American Flat	1863 - unknown	10
85	Granite	Gold Hill	1861 - 1870	28
86	Eclipse	Gold Hill	1861 - early 1870's	18
87	Comet[3]	Gold Hill	1861 - unknown	20

1. Number refers to the location of the mill on Figure 3.
2. Refers to the maximum crushing capacity reported during the operation of the mill.
3. Also was known as the McClellan Mill.

TABLE A.1 cont'd: Comstock Mills				
ID #[1]	Mill Name	General Location	Period of Operation	Capacity (tons/day)[2]
88	Bowers	Gold Hill	early 1860's - 1869	22
89	Crown Point	Gold Hill	1861 - unknown	8
90	Union	Gold Hill	1861 - unknown	14
91	Gold Hill	Gold Hill	1861 - 1875	18
92	Coover and Stevenson	Gold Hill	1860 - 1870's	10
93	Rhode Island	Gold Hill	1862 - 1874	40
94	Sapphire	Gold Hill	early 1860's - unknown	40
95	Petaluma	Gold Hill	1862 - mid 1870's	75
96	Imperial	Gold Hill	1860 - unknown	30
97	Empire	Gold Hill	1861 - unknown	32
98	Marysville	Gold Hill	1861 - unknown	36
99	Douglas	Gold Hill	1860 - late 1880's	30
100	Gould and Curry	Sixmile Canyon	1863 - 1871	100
101	Omega	Sixmile Canyon	1876 - 1881	100
102	Parke and Bowie	Sixmile Canyon	1867 - 1873	unknown
103	Empire State	Sixmile Canyon	early 1860's - 1880's	40
104	Sugar Loaf	Sixmile Canyon	early 1860's - unknown	10
105	Express	Sixmile Canyon	unknown	unknown

1. Number refers to the location of the mill on Figure 3.
2. Refers to the maximum crushing capacity reported during the operation of the mill.
3. Also was known as the Thistle Mill.

TABLE A.1 cont'd: Comstock Mills				
ID #[1]	Mill Name	General Location	Period of Operation	Capacity (tons/day)[2]
106	Janin	Sixmile Canyon	unknown	unknown
107	Roger's	Sixmile Canyon	early 1860's - 1870	14
108	Lady Bryan	Sixmile Canyon	early 1870's - early 1880's	20
109	Courser Bossel	Sixmile Canyon	unknown	unknown
110	Proctor[3]	Sixmile Canyon	1860's - unknown	unknown
111	Barrett[4]	Sixmile Canyon	unknown	unknown
112	Pfeifer	Sixmile Canyon	unknown	unknown
113	Hulley	Sixmile Canyon	early 1860's - unknown	30

1. Number refers to the location of the mill on Figure 3.
2. Refers to the maximum crushing capacity reported during the operation of the mill.
3. Also was known as the Rogers Mill.
4. Also was known as the Jennings Mill.

Appendix B

APPENDIX B

TABLE B.1: Assignment of Sample ID Numbers to Mills		
SAMPLE AREA ID	MILL	GENERAL LOCATION
MS001	Keller & Co.	Dayton
	Davis	Dayton
MS002	Mineral Rapids	Dayton
MS003	not a mill[1]	Dayton
MS004	French's	Dayton
	Birdsall	Dayton
	Winters	Dayton
MS005	Rock Point	Dayton
	Illinois	Dayton
MS006	not a mill	Dayton
MS007	Freeborn & Sheldon	Dayton
MS008	Succor	Dayton
MS009	Gautier	Dayton
MS010	Ophir	Dayton
MS011	New Ophir	Dayton
MS012	Morgan	Carson River
MS013	Brunswick	Carson River
MS014	unidentified mill	Carson River
MS015	Merrimac	Carson River
MS016	Santiago	Carson River
MS017	Eureka	Carson River
MS018	number was not assigned[2]	
MS019	Golden Age	Silver City
MS020	Devil's Gate	Silver City
MS021	Trench	Silver City
	Bacon	Silver City
MS022	McTigue	Silver City
MS023	Phoenix	Silver City
MS024	unnamed mill[3]	Silver City

TABLE B.1 cont'd: Assignment of Sample ID Numbers to Mills		
SAMPLE AREA ID	MILL	GENERAL LOCATION
MS025	Bartola	Silver City
MS026	Higgins	Silver City
MS027	Dayton	Silver City
MS028	Hope	Silver City
MS029	unnamed mill	Silver City
MS030	Union	Silver City
	Silver City	Silver City
MS031	Trimble	Silver City
MS032	Winters	Dayton
MS033	Empire	Virginia City
	Omega	Virginia City
	Nevada	Virginia City
	Odgen	Virginia City
	California Pan	Virginia City
MS034	Hoosier	Virginia City
MS035	Hale & Norcross	Virginia City
MS036	Hoosier	Virginia City
MS037	California Battery	Virginia City
	Consolidated	Virginia City
MS038	Sanborn	Virginia City
MS039	Gould & Carvill	Virginia City
MS040	Con Virginia	Virginia City
	Kendall	Virginia City
MS041	Arizona Comstock	Virginia City
MS042	Chollar	Virginia City
MS043	not a mill	Virginia City
MS044	Con-Chollar	Gold Hill
	Filter	Gold Hill
MS045	Rhode Island	Gold Hill

TABLE B.1 cont'd: Assignment of Sample ID Numbers to Mills		
SAMPLE AREA ID	**MILL**	**GENERAL LOCATION**
MS046	Overman	Gold Hill
MS047	Douglas	Gold Hill
MS048	unnamed mill	Gold Hill
MS049	Woodville	Gold Hill
	New Woodville	Gold Hill
MS050	Reed & Wade's Quartz	Gold Hill
MS051	Utah	Gold Hill
MS052	Rigby	Gold Hill
MS053	American Flat	Gold Hill
MS054	Baltimore	Gold Hill
MS055	Hartford	Gold Hill
MS056	New Occidental	Gold Hill
	Old Occidental	Gold Hill
MS057	unnamed mill	Gold Hill
MS058	Red Jacket	Gold Hill
MS059	Imperial	Gold Hill
MS060	Imperial	Gold Hill
MS061	unnamed mill	Gold Hill
MS062	Gold Hill	Gold Hill
MS063	Union	Gold Hill
MS064	Bowers	Gold Hill
MS065	Ramsdale	Gold Hill
MS066	Atlas	Gold Hill
MS067	Piute	Gold Hill
MS068	Saphire & Petaluma	Gold Hill
MS069	Granite & Eclipse	Gold Hill
MS070	Marysville	Gold Hill
MS071	Mexican	Gold Hill
TP007[4]	Janin	Sixmile Canyon
	Express	Sixmile Canyon
TP008	Roger's	Virginia City

TABLE B.1 cont'd: Assignment of Sample ID Numbers to Mills		
SAMPLE AREA ID	**MILL**	**GENERAL LOCATION**
TP010	Empire State	Sixmile Canyon
TP011	Park & Bowie	Sixmile Canyon
TP012	Gould & Curry	Virginia City
TP014	Atlantic	Virginia City
	Booth's	Virginia City
	Land's	Virgina City
TP015	Mexican	Virginia City
	Evans	Virginia City
TP016	Sierra	Virginia City

1. This area was identified as the staging area for tailings from the Birdsall Mill.
2. This number was mistakenly not assigned to a sampling area.
3. Several mills were identified which didn't have recorded names.
4. "TP" indicates that tailings were present near the mill.

TABLE B.2: Mercury Speciation in Soil, Samples Analyzed by Oak Ridge Research Institute[1] (mg/kg)					
Sample ID No.	Sample Date	Total Hg	Hg (0)	Hg_2S	Soluble Hg
DD 001-SL-10-A[2]	05/14/93	109.00	40.30	18.30	50.40
MS 001-SL-41-A[3]	04/28/93	97.50	97.40	56.50	0.00
MS 001-SL-51-A	04/28/93	121.00	72.30	72.00	0.00
MS 001-SL-59-A	05/18/93	43.70	26.90	5.30	11.50
MS 001-SL-89-A	08/19/93	22.10	18.90	6.20	0.00
MS 004-SL-02-A	05/06/93	297.00	131.00	16.60	149.00
MS 004-SL-14-A	05/07/93	326.00	111.40	51.70	129.00
MS 004-SL-33-A	08/19/93	58.30	49.20	8.10	1.00
MS 005-SL-12-A	05/12/93	176.00	28.20	59.80	88.50
MS 005-SL-16-A	05/12/93	124.00	86.60	45.20	0.00
MS 006-SL-09-A	05/14/93	51.00	25.70	21.60	3.60
MS 010-SL-69-A	05/25/93	790.00	495.50	58.10	235.05
MS 011-SL-48-A	06/03/93	55.60	54.60	0.02	1.00
MS 012-SL-09-A	06/03/93	396.00	387.00	3.30	5.20
MS 012-SL-37-A	06/03/93	1230.00	1230.00	15.80	0.00
MS 012-SL-38-A	06/03/93	780.00	777.00	13.30	0.00
MS 013-SL-12-A	06/03/93	39.50	38.80	0.02	0.64
MS 015-SL-02-A	06/10/93	798.00	794.00	13.80	0.00
MS 016-SL-01-A	06/10/93	112.00	111.00	0.76	0.70
MS 017-SL-03-A	06/02/93	1860.00	1840.00	22.40	0.00
MS 018-SL-01-A	06/03/93	655.00	646.00	11.20	0.00
MS 019-SD-04-A	07/01/93	624.00	620.00	14.10	0.00
MS 026-SL-06-A	07/15/93	36.60	36.20	6.40	0.00
TP 003-SL-01-A[4]	06/03/93	646.00	643.00	10.90	0.00
TP 004-SL-07-A	06/17/93	761.00	759.00	21.40	0.00
TP 005-SL-01-A	06/17/93	1480.00	1470.00	39.40	0.00
TP 005-SL-10-A	06/17/93	1200.00	1190.00	29.50	0.00
TP 007-SL-01-A	06/08/93	1650.00	1630.00	7.10	19.20
TP 007-SL-04-A	06/08/93	1400.00	1380.00	39.10	0.00

TABLE B.2 cont'd: Mercury Speciation in Soils, Samples Analyzed by Oak Ridge Research Institute[1]					
Sample ID No.	**Sample Date**	**Total Hg**	**Hg (0)**	**Hg_2S**	**Soluble Hg**
TP 008-SL-08-A	06/23/93	264.00	261.00	8.40	0.00
TP 011-SL-02-A	06/23/93	991.00	987.00	29.80	0.00
TP 011-SL-05-A	06/23/93	1060.00	999.00	25.70	35.90
TP 011-SL-09-A	06/23/93	1370.00	1360.00	29.20	0.00
TP 015-SL-11-A	07/01/93	41.20	39.00	12.50	0.00

1. Soil samples were also analyzed for methyl-mercury but this form of mercury was not found to exceed the Method Detection Limit of 2.8 mg/kg.
2. Sample identification prefix for samples collected from the "Dayton ditch."
3. Sample identification prefix for samples collected from historic millsites.
4. Sample identification prefix for samples collected from extant tailing piles.

TABLE B.3: Mercury Speciation in Soils, Samples Analyzed by EPA EMSL-Las Vegas					
Sample ID No.	**Sample Date**	**Total Hg**	**Hg (0)**	**Hg_2S**	**Soluble Hg**
MS 001-SL-41-A[1]	04/28/93	261.00	140.00	115.00	6.00
MS 005-SL-12-A	05/27/93	991.00	708.00	268.00	15.00
MS 012-SL-09-A	06/03/93	669.00	322.00	338.00	9.00
MS 012-SL-38-A	06/03/93	1154.00	94.00	948.00	112.00
MS 017-SL-03-A	06/10/93	3124.00	292.00	2826.00	6.00
TP 004-SL-07-A[2]	06/17/93	1632.00	207.00	1331.00	95.00
TP 007-SL-04-A	06/17/93	1273.00	294.00	937.00	42.00
TP 011-SL-05-A	06/23/93	2385.00	532.00	1845.00	8.00
TP 011-SL-09-A	06/23/93	1350.00	187.00	1154.00	10.00

1. Sample identification prefix for samples collected from historic millsites.
2. Sample identification prefix for samples collected from extant tailing piles.

TABLE B.4: Total Mercury in Surface Soils (< 6") at Historic Millsites and Extant Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum[a]	Mean[b]	Std Dev[c]	95 UCL[d]
MS001[e]	70	618	4	63	112	86
MS002	43	259	4	48	57	62
MS003	66	235	4	18	33	25
MS004	28	692	4	139	132	181
MS005	64	353	4	42	69	57
MS006	16	77	4	10	63	36
MS007	10	32	4	14	9	19
MS008	10	21	4	12	5	15
MS009	8	25	4	13	8	18
MS010	10	798	4	98	247	229
MS011	10	48	4	24	15	32
MS012	19	1731	4	225	591	453
MS013	20	968	4	90	213	170
MS014	10	10	4	5	2	6
MS015	14	1792	4	383	546	629
MS016	10	267	4	62	88	109
MS017	10	2551	4	516	871	978
MS018	6	1260	4	509	460	825
MS019	33	827	4	53	159	99
MS020	8	24	4	10	9	15
MS021	13	77	4	14	21	24
MS022	13	24	4	8	7	11
MS023	13	30	4	8	8	12
MS024	10	4	4	4	0	4
MS025	5	45	4	15	18	28
MS026	6	60	4	33	27	52
MS027	21	21	4	5	4	6
MS028	8	47	4	17	15	26
MS029	5	4	4	4	0	4

TABLE B.4: Total Mercury in Surface Soils (< 6") at Historic Millsites and Extant Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum[a]	Mean[b]	Std Dev[c]	95 UCL[d]
MS030	20	732	4	86	207	164
MS031	13	61	4	12	16	20
MS032	6	38	4	24	13	33
MS033	48	370	4	30	67	46
MS034	21	2516	4	130	547	331
MS035	3	4	4	4	0	4
MS036	8	1131	4	779	439	1040
MS037	10	14	4	6	4	8
MS038	8	31	4	9	10	15
MS039	8	4	4	4	0	4
MS040	24	6	4	4	0	4
MS041	9	4	4	4	0	4
MS042	7	20	4	6	6	10
MS043	3	4	4	4	0	4
MS044	14	4	4	4	0	4
MS045	6	44	4	12	16	23
MS046	8	501	4	73	173	176
MS047	18	206	4	29	54	51
MS048	12	4	4	4	0	4
MS049	12	84	4	12	23	24
MS050	10	10	4	5	2	6
MS051	3	4	4	4	0	4
MS052	5	88	4	22	37	49
MS053	18	10	4	4	1	5
MS054	3	4	4	4	0	4
MS055	5	4	4	4	0	4
MS056	14	1007	4	133	275	257
MS057	9	929	4	268	401	493
MS058	5	4	4	4	0	4

TABLE B.4: Total Mercury in Surface Soils (< 6") at Historic Millsites and Extant Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum[a]	Mean[b]	Std Dev[c]	95 UCL[d]
MS059	14	13	4	6	3	7
MS060	15	152	4	21	38	38
MS061	5	13	4	6	4	9
MS062	13	4	4	4	0	4
MS063	5	152	4	36	65	85
MS064	2	4	4	4	0	4
MS065	3	5	4	4	1	5
MS066	3	737	4	250	422	659
MS067	3	4	4	4	0	4
MS068	6	40	4	19	13	28
MS069	6	55	4	14	20	28
MS070	3	4	4	4	0	4
MS071	10	219	4	76	76	117
TP001[f]	7	14	4	5	4	8
TP002	9	4	4	4	0	4
TP003	6	1039	4	729	398	1002
TP004	16	904	4	331	310	462
TP005	6	937	8	269	361	516
TP006	6	691	4	191	295	393
TP007	22	4672	4	916	1125	1319
TP008	11	350	4	139	147	213
TP009	5	700	4	336	318	575
TP010	3	34	9	18	14	31
TP011	11	1843	4	693	646	1021
TP012	10	308	10	62	94	112
TP013	12	198	4	23	55	50
TP014	16	14	4	7	4	8
TP015	18	99	4	10	22	19
TP016	13	22	4	5	5	8

TABLE B.4: Total Mercury in Surface Soils (< 6") at Historic Millsites and Extant Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum[a]	Mean[b]	Std Dev[c]	95 UCL[d]
TP017	10	1300	4	587	525	866
TP018	5	1606	4	478	658	972
TP019	4	4	4	4	0	4
TP020	10	4	4	4	0	4
TP021	9	4	4	4	0	4
TP022	1	230	230	230	9	0
DD001[g]	11	109	4	26	38	46

a. The method detection limit (MDL) was 8 mg/kg, therefore, levels below the MDL are reported as 1/2 the MDL (4 mg/kg).
b. Abbreviation for the arithmetic mean.
c. Abbreviation for standard deviation.
d. Abbreviation for the 95% upper confidence limit, normal distribution.
e. Prefix for samples collected from historic millsites.
f. Prefix for samples collected from extant tailing piles.
g. Prefix for samples collected from the Dayton Ditch.

TABLE B.5: Total Arsenic in Surface Soils (< 6"): Historic Millsites and Extant Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum	Mean[a]	Std. Dev.[b]	95 UCL[c]
MS001[d]	8	14	9	11	2	12
MS002	5	66	11	25	23	42
MS003	6	23	3	12	8	17
MS004	3	32	6	16	14	30
MS005	4	55	5	25	21	43
MS006	1	17	17	17	**	**
MS008	1	8	8	8	**	**
MS009	1	3	3	3	**	**
MS010	1	9	9	9	**	**
MS011	1	10	10	10	**	**
MS012	2	15	14	14	0	15
MS013	1	20	20	20	**	**
MS014	1	8	8	8	**	**
MS015	1	10	10	10	**	**
MS016	1	11	11	11	**	**
MS017	1	11	11	11	**	**
MS019	15	68	11	38	20	47
MS020	3	22	12	17	5	21
MS021	4	518	16	145	249	354
MS022	3	31	14	22	9	31
MS023	1	26	26	26	**	**
MS024	1	21	21	21	**	**
MS026	1	23	23	23	**	**
MS027	2	21	16	19	4	23
MS028	3	18	14	16	2	18
MS029	1	13	13	13	**	**
MS031	4	96	11	41	39	73

TABLE B.5: Total Arsenic in Surface Soils (< 6"): Historic Millsites and Extant Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum	Mean[a]	Std. Dev.[b]	95 UCL[c]
MS033	5	13	3	9	4	12
MS034	1	11	11	11	**	**
MS035	1	6	6	6	**	**
MS039	3	13	8	10	3	12
MS040	9	16	5	12	4	14
MS041	1	1	1	1	**	**
MS044	2	12	10	11	1	12
MS046	1	160	160	160	**	**
MS047	1	22	22	22	**	**
MS048	1	21	21	21	**	**
MS049	1	22	22	22	**	**
MS050	1	14	14	14	**	**
MS053	2	18	15	17	2	19
MS055	1	21	21	21	**	**
MS056	1	3	3	3	**	**
MS057	2	47	15	31	23	58
MS059	1	16	16	16	**	**
MS060	1	8	8	8	**	**
MS062	1	15	15	15	**	**
TP[e]	16	627	4	55	153	119

a. Abbreviation for arithmetic mean.
b. Abbreviation for standard deviation.
c. Abbreviation for 95% upper confidence limit, normal distribution.
d. Prefix for millsite sample areas.
e. Prefix for all tailing pile sample areas (TP001 - TP022)

TABLE B.6: Total Lead in Surface Soils (< 6"): Historic Millsites and Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum	Mean[a]	Std. Dev.[b]	95UCL[c]
MS001[d]	8	216	11	82	75	127
MS002	5	566	41	217	204	370
MS003	6	65	5	27	23	43
MS004	3	429	238	354	102	452
MS005	4	319	16	107	142	227
MS006	1	30	30	30	**	**
MS008	1	32	32	32	**	**
MS009	1	3	3	3	**	**
MS010	1	46	46	46	**	**
MS011	1	43	43	43	**	**
MS012	2	887	207	547	481	1118
MS013	1	282	282	282	**	**
MS014	1	24	24	24	**	**
MS015	1	153	153	153	**	**
MS016	1	34	34	34	**	**
MS017	1	139	139	139	**	**
MS019	15	887	31	163	222	259
MS020	3	53	49	51	2	53
MS021	4	6100	36	1556	3029	4101
MS022	3	155	86	109	40	148
MS023	1	49	49	49	**	**
MS024	1	18	18	18	**	**
MS026	1	60	60	60	**	**
MS027	2	290	57	173	165	369
MS028	3	137	78	105	30	134
MS029	1	36	36	36	**	**
MS031	4	434	22	200	192	362

TABLE B.6: Total Lead in Surface Soils (< 6"): Historic Millsites and Tailing Piles (mg/kg)						
Area	Size	Maximum	Minimum	Mean[a]	Std. Dev.[b]	95UCL[c]
MS033	5	650	127	367	202	519
MS034	1	1300	1300	1300	**	**
MS035	1	387	387	387	**	**
MS039	3	685	172	470	267	729
MS040	9	375	0	169	116	235
MS041	1	1	1	1	**	**
MS044	2	103	43	73	42	123
MS046	1	22	22	22	**	**
MS047	1	52	52	52	**	**
MS048	1	31	31	31	**	**
MS049	1	157	157	157	**	**
MS050	1	41	41	41	**	**
MS053	2	166	50	108	82	205
MS055	1	274	274	274	**	**
MS056	1	453	453	453	**	**
MS057	2	0	0	0	0	0
MS059	1	0	0	0	**	**
MS060	1	0	0	0	**	**
MS062	1	0	0	0	**	**
TP[e]	16	3020	26	763	867	1127

a. Abbreviation for arithmetic mean.
b. Abbreviation for standard deviation.
c. Abbreviation for 95% upper confidence limit, normal distribution.
d. Prefix for millsite sample areas.
e. Prefix for tailing pile sample areas (TP001 - TP022).

TABLE B.7: Total Mercury in Surface Soils (< 6"): Alluvial Fan, Flood Plain, Washoe Lake, and Pleasant Valley Sample Areas (mg/kg)						
Area	Size	Maximum	Minimum[a]	Mean[b]	Std Dev[c]	95 UCL[d]
AF001[e]	26	285	4	37	60	57
FA001[f]	12	44	3	10	11	15
FA002	14	28	4	7	7	10
FA003	6	18	4	7	6	11
FA004	4	4	4	4	0	4
FA005	2	4	4	4	0	4
FA006	2	4	4	4	0	4
FA007	3	4	4	4	0	4
FA008	11	36	4	8	10	13
FA009	5	62	4	25	23	42
FA010	14	366	4	69	124	125
FA011	5	4	4	4	0	4
FA012	5	29	4	20	11	29
FA013	5	4	4	4	0	4
FA014	3	4	4	4	0	4
FA015	5	13	4	9	4	12
FA016	5	9	4	5	2	6
FP001[f]	19	52	4	24	16	30
FP002	10	16	4	6	4	9
FP003	18	254	4	25	59	48
FP004	9	38	4	15	11	21
PV001[g]	4	105	4	18	35	39
PV002	11	117	4	16	34	33
WL001[h]	6	19	4	8	7	13
WL002	5	38	4	11	15	22
WL003	7	4	4	4	0	4
WL004	6	43	4	11	16	21
WL005	4	14	4	7	5	11

TABLE B.7: Total Mercury in Surface Soils (< 6"): Alluvial Fan, Flood Plain, Washoe Lake, and Pleasant Valley Sample Areas (mg/kg)						
Area	Size	Maximum	Minimum[a]	Mean[b]	Std Dev[c]	95 UCL[d]
WL006	2	53	12	33	29	67

a. The method detection limit (MDL) was 8 mg/kg, therefore, levels below the MDL are expressed as 1/2 the MDL (4 mg/kg).
b. Abbreviation for arithmetic mean.
c. Abbreviation for standard deviation.
d. Prefix for alluvial fan sampling areas.
e. Prefix for flood plain sampling areas below Lahontan Dam.
f. Prefix for flood plain sampling areas above Lahontan Dam.
g. Prefix for Pleasant Valley sampling areas.
h. Prefix for Washoe Lake sampling areas

TABLE B.8: Total Arsenic in Surface Soils (< 6"): Alluvial Fan and Flood Plain (mg/kg)						
Area	Size	Maximum	Minimum	Mean[a]	Std. Dev.[b]	95 UCL[c]
AF001[d]	2	11	8	9	2	12
FA001[e]	9	8	4	6	1	6
FA002	9	10	3	5	2	6
FA004	1	11	11	11	**	**
FA008	8	16	5	8	4	11
FA010	10	18	6	12	4	14
FA012	1	18	18	18	**	**
FA016	1	3	3	3	**	**
FA017	1	5	5	5	**	**
FP001[f]	9	15	9	12	2	13
FP002	1	10	10	10	**	**
FP003	9	8	5	6	1	7
FP004	1	12	12	12	**	**

a. Abbreviation for arithmetic mean.
b. Abbreviation for standard deviation.
c. Abbreviation for 95% upper confidence limit, normal distribution.
d. Prefix for alluvial fan sample area.
e. Prefix for flood plain sample areas below Lahontan Dam.
f. Prefix for flood plain sample areas above Lahontan Dam.

TABLE B.9: Total Lead in Surface Soils (< 6"): Alluvial Fan and Flood Plain (mg/kg)						
Area	Size	Maximum	Minimum	Mean[a]	Std. Dev.[b]	95UCL[c]
AF001[d]	2	192	113	153	56	219
FA001[e]	9	19	4	9	6	0
FA002	9	10	5	7	2	8
FA004	1	0	0	0	**	**
FA008	8	11	3	6	3	8
FA010	10	49	0	22	16	31
FA012	1	0	0	0	**	**
FA016	1	0	0	0	**	**
FA017	1	0	0	0	**	**
FP001[f]	9	52	31	43	7	47
FP002	1	8	8	8	**	**
FP003	9	9	5	6	1	7
FP004	1	36	36	36	**	**

a. Abbreviation for arithmetic mean.
b. Abbreviation for standard deviation.
c. Abbreviation for 95% upper confidence limit, normal distribution.
d. Prefix for alluvial fan sample area.
e. Prefix for flood plain sample areas below Lahontan Dam.
e. Prefix for flood plain sample areas above Lahontan Dam.

TABLE B.10a: Total Mercury in Subsurface Soil (Samples Collected with Hand Auger) (mg/kg)						
Sample ID No.	Feet Below Ground Surface					
	0 - 0.50	0.5 - 1.00	1.00 - 1.50	1.50 - 2.00	2.00 - 3.00	3.00 - 4.00
FA 011-SL-01	4	NS[1]	4	NS	NS	NS
FA 011-SL-02	4	NS	4	NS	NS	NS
FA 011-SL-03	4	NS	4	NS	NS	NS
FA 017-SL-01	4	NS	4	NS	NS	NS
FA 017-SL-03	4	4	NS	4	NS	NS
FP 001-SL-01	4	NS	4	NS	NS	NS
MS 001-SL-60	144	223	NS	NS	217	NS
MS 001-SL-64	4	4	NS	NS	NS	NS
MS 004-SL-34	19	14	NS	NS	NS	NS
MS 005-SL-62	9	NS	42	NS	NS	13
MS 005-SL-64	30	NS	4	NS	NS	19
MS 010-SL-33	4	NS	704	NS	NS	NS
MS 011-SL-54	15	NS	21	NS	NS	NS
MS 012-SL-38	988	NS	1135	NS	NS	NS
MS 013-SL-04	4	4	NS	NS	NS	NS
MS 013-SL-08	4	NS	NS	4	NS	4
1. Not sampled						

TABLE B.10b: Total Mercury in Subsurface Soil (mg/kg) (Samples Collected from Channel Banks)						
Sample ID No.	Feet Below Top of Bank					
	0 - 0.50	0.5 - 1.00	1.00 - 1.50	1.50 - 2.00	2.00 - 3.00	3.00 <
AF 001-SL-02	4	NS[1]	NS	NS	NS	15
AF 001-SL-05	25	NS	NS	NS	NS	73
AF 001-SL-07	8	11	NS	NS	NS	NS
AF 001-SL-11	15	10	NS	NS	NS	NS
AF 001-SL-12	17	4	NS	NS	NS	NS
AF 001-SL-14	28	15	NS	NS	NS	NS
AF 001-SL-17	11	4	NS	NS	24.18	221
AF 001-SL-18	22	NS	NS	NS	NS	4
AF 001-SL-23	13	NS	12	62	NS	NS
AF 001-SL-26	45	NS	NS	16	42.43	NS
DD 001-SL-02	4	NS	NS	23	NS	NS
DD 001-SL-13	4	NS	NS	NS	NS	4
FA 010-SL-05	4	NS	NS	NS	NS	4
FA 011-SL-05	4	NS	NS	NS	NS	4
FA 013-SL-04	4	NS	NS	NS	4.00	NS
FA 017-SL-04	4	NS	NS	NS	NS	4
FP 005-SL-01	NS	NS	NS	23	NS	298
MS 048-SL-07	4	4	NS	NS	NS	NS
MS 056-SL-14	141	NS	NS	NS	NS	524
PV 002-SL-06	117	NS	NS	NS	12.48	NS

TABLE B.11a: Concentrations of Select Trace Metals Measured in Surface Soil Samples (0 - 6") from Lahontan Reservoir Beach Areas			
Sample #	Total Concentration (mg/kg)		
	As	Hg	Pb
LR-01	3.00	0.20	3.50
LR-02	4.00	<0.1	3.50
LR-03	3.00	<0.1	3.50
LR-04	2.50	<0.1	3.50
LR-06	<2.50	0.20	3.50
LR-08	3.50	<0.1	3.50
LR-09	3.00	0.20	3.00
LR-10	4.00	0.20	3.00
LR-12	3.00	0.20	2.50
LR-13	3.50	0.20	3.00
LR-14	4.00	0.20	3.00
LR-17	3.00	0.20	4.50
LR-19	9.00	0.20	4.00
LR-20	19.00	0.10	10.00
LR-21	5.50	<0.1	4.00
LR-25	7.50	<0.1	3.50
LR-26	10.00	<0.1	2.00
LR-27	13.50	0.20	5.50
LR-28	10.00	<0.1	2.00
LR-29	7.50	<0.1	1.50
LR-32	7.50	<0.1	2.50
LR-33	22.50	<0.1	9.50
LR-34	16.50	<0.1	9.00
LR-36	78.00	0.30	9.00
LR-37	10.00	0.20	4.00
Source: Bureau of Reclamation, 1993a			

TABLE B.11b cont'd: Concentrations of Select Trace Metals Measured in Subsurface Soil Samples (6 - 12") from Lahontan Reservoir Beach Areas			
Sample #	Total Concentration (mg/kg)		
	As	Hg	Pb
LR-02	4.00	<0.1	3.50
LR-04	2.50	<0.1	3.00
LR-08	3.00	<0.2	3.50
LR-10	<2.50	<0.1	1.50
LR-13	3.50	<0.3	3.00
LR-21	18.00	<0.1	8.50
LR-29	10.50	<0.1	2.00
LR-37	11.00	<0.2	4.00
Source: Bureau of Reclamation, 1933			

TABLE B.12: Concentration of Select Trace Metals Measured in Surface Soil Samples (0 - 6") from Indian Lakes			
Sample #	Total Concentration (mg/kg)		
	As	Hg	Pb
IL-01	3.70	0.36	<5.0
IL-02	1.80	0.12	<5.0
IL-03	12.90	4.10	5.70
IL-04	5.00	0.10	7.00
IL-05	3.80	0.45	6.40
IL-06	12.60	2.90	7.80
IL-07	10.50	0.24	<5.0
IL-08	9.40	0.35	<5.0
IL-09	12.40	0.20	<5.0
IL-10	9.40	0.60	6.70
IL-11	18.40	0.47	13.80
IL-12	2.00	<0.06	6.90
IL-13	16.40	0.81	5.50
IL-14	11.60	0.68	6.60
IL-15	6.60	0.07	<5.0
IL-16	9.40	0.44	11.20
IL-17	6.80	0.06	6.30
IL-18	2.20	<0.06	<5.0
IL-19	8.40	0.16	<5.0
IL-20	7.50	0.08	6.00
IL-21	2.60	<0.06	5.30
Source: Bureau of Reclamation, 1993b			

TABLE B.13: Total Mercury Statistics for Subareas (mg/kg)							
SAMPLE AREA	SIZE	MAX	MIN[a]	AVE[b]	STD[c]	95UCL[d]	AREA (m^2)
DD001-SA[e]	4	109	9	62	46	100	739
MS001-SA[f]	43	618	4	95	134	129	9703
MS002-SA	26	259	4	69	57	88	5344
MS003-SA	12	235	22	63	58	91	2997
MS004-SA1	5	66	28	47	15	58	3415
MS004-SA2	15	692	4	149	188	231	3873
MS005-SA-1	20	353	4	103	109	143	18305
MS005-SA-2	5	64	9	40	22	56	1051
MS005-SA-3	11	60	29	43	11	49	2958
MS010-SA	4	798	31	231	378	548	836
MS011-SA	7	48	4	30	20	43	7319
MS012-SA	13	1731	4	285	497	517	12457
MS013-SA	12	968	4	130	267	259	27197
MS015-SA	11	1792	38	486	578	779	7972
MS016-SA	6	267	18	97	101	167	2985
MS017-SA	9	2551	28	572	904	1079	4910
MS018-SA	5	1260	111	485	477	843	894
MS019-SA	8	827	4	195	292	369	3312
MS026-SA	4	60	17	48	21	66	849
MS030-SA	5	732	53	326	328	572	1152
MS032-SA	7	356	14	105	136	191	5813

TABLE B.13: Total Mercury Statistics for Subareas (mg/kg)							
SAMPLE AREA	SIZE	MAX	MIN	AVE[a]	STD[b]	95UCL[c]	AREA (m^2)
MS033-SA	28	370	85	46	85	73	22150
MS036-SA	7	1131	185	890	333	1101	2549
MS046-SA	2	501	36	268	329	659	418
MS047-SA	9	737	4	135	236	267	4461
MS056-SA	6	1007	4	306	366	557	13092
MS057-SA	3	929	634	793	149	938	434
MS060-SA	2	152	52	102	71	186	486
MS071-SA	8	219	4	90	79	137	15440
TP003-SA[g]	5	1039	544	874	200	1025	1429
TP004-SA	13	904	26	407	296	545	7343
TP005-SA	4	937	11	396	389	723	1474
TP006-SA	2	691	419	555	193	784	1201
TP007-SA	20	4672	66	1007	1142	1436	20767
TP008-SA	8	350	19	189	143	274	2978
TP009-SA	4	700	51	419	299	670	851
TP011-SA	11	1843	4	690	643	1016	4666
TP012-SA	7	308	10	82	108	150	16183
TP017-SA	8	1300	22	733	483	1020	5172
TP018-SA	3	1606	382	791	706	1476	119
FP001-SA[h]	12	52	39	32	13	39	4235

TABLE B.13: Total Mercury Statistics for Subareas (mg/kg)							
SAMPLE AREA	SIZE	MAX	MIN	AVE[a]	STD[b]	95UCL[c]	AREA (m^2)
FA010-SA[i]	6	351	4	90	129	178	1067

a. Concentrations reported to be equal to or less than the Method Detection Limit of 8 ppm are reported as 1/2 the detection limit, 4ppm.
b. Abbreviation for arithmetic mean.
c. Abbreviation for standard deviation.
d. Abbreviation for the 95th percent upper confidence limit.
e. Prefix for samples collected from the Dayton Ditch.
f. Prefix for samples collected from historic millsites.
g. Prefix for samples collected from extant tailing piles.
h. Prefix for samples collected from the flood plain above Lahontan Reservoir.
i. Prefix for samples collected from the flood plain below Lahontan Reservoir.

TABLE B.14: Total Mercury in Sediments						
General Location	Sampling Location	Sample Date	Sample Size	Total Hg (mg/kg)		Source
				Range	Mean	
Big Washoe Lake	not specified	8/2/88	6	39.80 - 100.30	59.97	NDEP, 1988
Little Washoe Lake	not specified	9/18/87	16	0.25 - 7.40	3.72	NDEP, 1988
Btw. New Empire and Dayton	New Empire	12/1/70	1	-	0.44	Van Denburgh, 1973
		9/22/71	1	-	0.98	Van Denburgh, 1973
		1975	1	-	0.12	Richins & Risser, 1975
		5/83 - 12/84	5	<0.25 - 0.40	0.08	Cooper et al., 1985
	Santiago Mill	5/83 - 12/84	4	<0.25 - 0.68	0.27	Cooper et al., 1985
	Eureka Mill	9/22/71	1	-	1.2	Van Denburgh, 1973
		1975	1	-	0.35	Richins & Risser, 1975
Btw. Dayton and Six Mile Canyon Confluence	Dayton Bridge	12/1/70	1	-	2.1	Van Denburgh, 1973
		9/21/71	1	-	0.31	Van Denburgh, 1973
		5/83 - 12/84	5	0.35 - 0.97	0.71	Cooper et al., 1985
	0.6 miles below Dayton	1975	1	-	0.21	Richins & Risser, 1975
Btw. Six Mile Canyon Confluence and Fort Churchill	6 miles east of Dayton	1975	1	-	0.72	Richins & Risser, 1975
	7 miles east of Dayton	12/1/70	1	-	3.70	Van Denburgh, 1973
		9/21/71	1	-	3.50	Van Denburgh, 1973
	Chaves Ranch	5/83 - 12/84	5	0.93 - 5.00	2.57	Cooper et al., 1985
	2 miles west of Ft. Churchill	12/1/70	1	-	11.00	Van Denburgh, 1973
		9/21/71	1	-	6.80	Van Denburgh, 1973

TABLE B.14 cont'd: Total Mercury in Sediments						
General Location	**Sampling Location**	**Sample Date**	**Sample Size**	**Total Hg (mg/kg)**		**Source**
				Range	Mean	
Btw. Ft. Churchill and the Mouth of Lahontan Reservoir	Weeks Bridge	5/83 - 12/84	5	0.70 - 8.55	3.09	Cooper et al., 1985
Lahontan Reservoir	Upstream end	6/14/72	1	-	12.00	Van Denburgh, 1973
	not specified	1975	1	-	1.35	Richins & Risser, 1975
	Narrows	6/14/72	1	-	20.00	Van Denburgh, 1973
	Various locations	5/2/85	9	2.80 - 30.50	15.00	Cooper et al., 1985
	Near Dam	6/14/72	1	-	5.3	Van Denburgh, 1973
Below Lahontan Reservoir	Below Lahontan Dam	5/83 - 12/84	4	0.80 - 2.65	1.78	Cooper et al., 1985
	South Branch at Sheckler Road	5/83 - 12/84	4	2.27 - 23.75	9.39	Cooper et al., 1985
	L Drain Near Fallon Air Station	5/83 - 12/84	4	0.72 - 4.25	1.91	Cooper et al., 1985
	Stillwater Slough Cutoff	5/83 - 12/84	4	3.25 - 6.75	4.89	Cooper et al., 1985
Stillwater Refuge	Stillwater Point Reservoir Outlet	5/83 - 12/84	4	<0.25	<0.25	Cooper et al., 1985

TABLE B.15: Summary of Sampling Results for Drinking Water Sampled in Dayton and Mark Twain (ug/l)				
Sample ID	**Sample Date**	**As**	**Hg**	**Pb**
DW 001-GW-01-A	07/14/93	5	0.2	0.6
DW 001-GW-02-A	07/14/93	1.1	0.1	0.6
DW 001-GW-03-A	07/14/93	2.4	0.1	0.6
DW 001-GW-04-A	07/14/93	1.1	0.1	14
DW 001-GW-05-A	07/14/93	1.1	0.1	0.6
DW 001-GW-06-A	07/14/93	7.4	0.1	0.6
DW 001-GW-07-A	07/14/93	1.1	0.1	0.6
DW 001-GW-08-A	07/14/93	1.1	0.2	0.6
DW 001-GW-09-A	07/14/93	1.1	0.1	0.6
DW 001-GW-10-A	07/14/93	4.2	0.1	15
DW 001-GW-11-A	07/14/93	1.1	0.1	0.6
DW 002-GW-01-A	07/15/93	1.1	0.1	0.6
DW 002-GW-02-A	07/15/93	1.1	0.1	0.6
DW 002-GW-03-A	07/15/93	1.1	0.1	0.6
DW 002-GW-04-A	07/15/93	1.1	0.1	0.6
DW 002-GW-05-A	07/15/93	1.1	0.1	0.6
DW 002-GW-06-A	07/15/93	1.1	0.1	0.6
DW 002-GW-07-A	07/15/93	138	0.2	5.4
DW 002-GW-07-A	08/18/94	7.8	0.1	72.4
D 002-GW-08-A	07/15/93	1.1	0.1	0.6
DW 002-GW-09-A	07/15/93	1.1	0.1	0.6
DW 002-GW-10-A	07/15/93	1.1	0.1	0.6
DW 002-GW-11-A	07/15/93	1.1	0.1	0.6
DW 002-GW-12-A	07/15/93	4.7	0.1	0.6
DW 002-GW-13-A	07/15/93	3.15	0.1	0.6
DW 002-GW-14-A	07/15/93	1.1	0.1	0.6
DW 003-GW-01-A	07/16/93	1.1	0.1	0.6
DW 003-GW-02-A	07/16/93	1.1	0.1	0.6

1. Method Detection Limit for Arsenic = 10 ug/l
2. Method Dection Limit for Mercury = 0.20 ug/l
3. Method Dection Limit for Lead = 3.0 ug/l

TABLE B.16: Summary of Surface Water Data for Lahontan Reservoir (mg/l)			
Sample ID	**As**	**Hg**	**Pb**
CR-01	<0.05	0.0015	<0.03
LRW-13	<0.05	0.0022	<0.03
LRW-14	<0.05	0.0002	<0.03
LRW-17	<0.05	0.0003	<0.03
LRW-20	<0.05	<0.0002	<0.03
LRW-26	<0.05	<0.0002	<0.03
CR-02	<0.05	<0.0002	<0.03
TR-01	<0.05	<0.0002	<0.03
Source: Bureau of Reclamation, 1993a			

TABLE B.17: Indoor Air Sampling Results for Dayton					
Sample ID #	Sampling Location	Sample Time (min.)	Flow Rate (ml/min.)	Date Collected	Total Hg (ug/m^3)1
DA01AV-001	Dayton #1	480	249.7	8/9/93	0.11
DA01AV-002	Dayton #2	480	252.9	8/9/93	0.11
DA01AV-003	Dayton #3	480	248.7	8/9/93	0.11
DA01AV-004	Duplicate of DA01AV-003	480	251.8	8/9/93	0.11
DA01AV-005	Dayton #4	480	253.5	8/9/93	0.11
DA01AV-006	Blank	480	250	8/9/93	0.11
DA01AV-007	Dayton #5	480	230.8	8/10/93	0.11
DA01AV-008	Duplicate of DA01AV-007	480	246.0	8/10/93	0.11
DA01AV-009	Dayton #4	480	255.9	8/10/93	0.11
DA01AV-010	Dayton #1	480	257.6	8/10/93	0.11
DA01AV-011	Dayton #6	480	254.1	8/10/93	0.11
DA01AV-012	Dayton #7	480	254.4	8/10/93	0.11
DA01AV-013	Dayton #8	390	255.9	8/10/93	0.11
DA01AV-014	Dayton #9	480	256.1	8/10/93	0.11
DA01AV-015	Dayton #10	480	260.4	8/11/93	0.11
DA01AV-016	Dayton #11	480	250.6	8/11/93	0.11
DA01AV-017	Dayton #12	480	253.6	8/11/93	0.11
DA01AV-018	Dayton #13	480	259.6	8/11/93	0.11

1. Non-detects are reported as 1/2 the method detection limit of 0.21 ug/m3.

TABLE B.17 cont'd: Indoor Air Sampling Results for Dayton					
Sample ID #	**Sampling Location**	**Sample Time (min.)**	**Flow Rate (ml/min.)**	**Date Collected**	**Total Hg (ug/m^3)**
DA01AV-019	Duplicate of DA01AV-018	480	257.8	8/11/93	0.21
DA01AV-020	Dayton #4	480	251.3	8/11/93	0.21
DA01AV-021	Dayton #14	446	258.4	8/11/93	0.22
DA01AV-022	Dayton #1	480	258.1	8/11/93	0.21
DA01AV-023	Blank Sample	480	250	8/11/93	0.21
DA01AV-024	Blank Sample	480	250	8/10/93	0.21
DA01AV-025	Dayton #15	480	260.8	8/12/93	0.21
DA01AV-026	Blank Sample	480	250	8/12/93	0.21
Method Detection Limit = 0.21 ug/m3					

TABLE B.18: Summary of Total Mercury Measured in Vegetables, Fruit, and Root Soil (mg/kg)							
Soil		Vegetables and Fruit					
Sample ID[1]	Total [Hg]	Sample ID	Type	Location	Sample Size	Total [Hg] dry wt.	Total[Hg]wet wt.
AG002-SL-01A	78.5	AG002-VG-01A	Tomato	Dayton	3	0.51	0.04
AG002-SL-02A	149.5	AG002-VG-02A	Green Onion	Dayton	3	0.34	0.04
		AG002-VG-03A	Broccoli	Dayton	2	0.27	0.04
		AG002-VG-04A	Zucchini	Dayton	1	1.00	0.04
		AG002-VG-05A	Squash Leaves w/o Squash	Dayton	3	2.30	0.41
		AG002-VG-06A	Sweet Pea Plan & Flower	Dayton	1	1.30	0.64
AG004-SL-01A	28.9	AG004-VG-01A	Carrot w/Top	Dayton	1	2.10	0.22
		AG004-VG-02A	Beet w/Stalk	Dayton	1	0.99	0.12
		AG004-VG-03A	Green Beans	Dayton	5	0.20	0.04
		AG004-VG-04A	Tomato	Dayton	2	0.67	0.04
AG005-SL-02A	148.7	AG005-VG-01A	Zucchini	Dayton	1	1.20	0.05
		AG005-VG-02A	Tomato	Dayton	3	0.53	0.04
		AG005-VG-03A	Cucumber	Dayton	1	1.20	0.05
		AG005-VG-04A	Apple	Dayton	6	0.21	0.04

1. Sampling locations are indicated in Figure 17 according to the soil sample ID.

TABLE B.18 cont'd: Summary of Total Mercury Measured in Vegetables, Fruit, and Root Soil (mg/kg)							
Soil		**Vegetables and Fruit**					
Sample ID	**Total [Hg]**	**Sample ID**	**Type**	**Location**	**Sample Size**	**Total [Hg] dry wt.**	**Total [Hg] wet wt.**
AG007-SL-01A	29.3	AG007-VG-01A	Lettuce	Dayton	3 leaves	1.00	0.04
		AG007-VG-02A	Radishes	Dayton	3	8.00	0.64
AG007-SL-02A	24.5	AG007-VG-03A	Tomato	Dayton	5	0.87	0.05
		AG007-VG-04A	Carrot	Dayton	2	1.00	0.10
		AG007-VG-05A	Corn kernels	Dayton	1 ear	0.20	0.07
AG009-SL-01A	22.2	AG009-VG-01A	Peaches	Silver City	3	0.35	0.05
AG009-SL-02A	4.00	AG009-VG-02A	Apricot	Silver City	4	0.30	0.05
		AG009-VG-03A	Apple	Silver City	3	0.03	0.06
1. Sampling locations are indicated in Figure 17 according to soil sample ID.							

TABLE B.19: Total Mercury in Bullrush Root ("Tules")					
General Location	Sampling Location	Date	Percent Moisture	Total Mercury (mg/kg)	
				Dry Weight	Wet Weight
Carson Lake	Islands Unit	9/23/86	80.03	1.60	0.32
	Sprig Ponds	10/03/86	82.75	0.43	0.07
			86.39	0.79	0.11
	Sump	9/23/86	85.93	<0.29	0.04[a]
			89.90	0.80	0.08
	#1 Deep Drain	6/30/87	90.30	<0.26	0.03
	#1A Deep Drain	7/20/87	88.60	<0.22	0.03
	Mid Deep Drain	6/30/87	80.80	0.22	0.04
	Upper Deep Drain	6/30/87	82.70	0.58	0.10
	Downs Drain	7/14/87	92.00	1.28	0.10
	J1 Deep Drain	2/22/87	90.60	<0.27	0.03
	L Deep Drain	6/29/87	83.00	0.31	0.05
	Pasture Road Drain	6/30/87	88.20	<0.21	0.02
	Pier L Deep Drain	6/22/87	86.20	<0.18	0.02
		8/24/87	96.70	0.18	0.01
	Yarbrough Drive	7/14/87	88.00	1.57	0.19

TABLE B.19 cont'd: Total Mercury in Bullrush Root ("Tules")					
General Location	**Sampling Location**	**Date**	**Percent Moisture**	**Total Mercury (mg/kg)**	
				Dry Weight	**Wet Weight**
Stillwater Refuge	Alkali Unit #1	9/16/86	87.80	<0.41	0.05
			82.04	<0.27	0.05
			84.60	<0.30	0.05
	Goose Lake	9/30/86	82.20	<0.28	0.05
		10/02/86	82.91	<0.28	0.05
			85.65	<0.29	0.04
	Swan Lake Check	7/16/87	87.50	0.51	0.06

Source: Hoffman et al., 1990
a. Wet weight values are calculated with the detection limit value (i.e., 0.29).

TABLE B.20: Total Mercury in Muscle Tissue of White Bass Collected from Washoe Lake and the Carson River System							
General Location	**Sampling Location**	**Sample Size**	**Average Weight (grams)**	**Average Length (inches)**	**Hg Range (mg/kg, wet weight)**	**Average Hg (mg/kg, wet weight)**	**Data Source**
Big Washoe Lake	not specified	34	108.10	7.5	0.14 - 1.55	0.52	NDEP, 1987
Little Washoe Lake	not specified	13	92.11	6.15	0.07 - 2.30	0.58	NDEP, 1987
Carson River Above Lahontan Dam	Fort Churchill Gage	2	--	7.5	3.10 - 3.19	3.14	Cooper et. al. 1985
Lahontan Reservoir	not specified	8	414.23	--	0.48 - 1.09	0.74	Richins & Risser 1975
	not specified	8	158.38	--	0.97 - 3.95	2.45	Cooper 1983
	not specified	23	--	7.2	0.41 - 1.80	1.08	NDOW[1] 1984
	not specified	8	159.00	--	0.97 - 3.95	2.45	NDOW 1981
	not specified	13	157.00	8.44	0.85 - 3.96	2.63	NDOW 1986
	not specified	13	137.73	7.45	0.29 - 2.65	1.53	NDOW 1987
	not specified	19	200.60	9.15	0.68 - 5.10	2.41	NDOW 1988
	not specified	6	152.50	7.93	0.27 - 3.28	1.58	NDOW 1989
	not specified	10	176.00	8.13	0.39 - 2.30	1.27	NDOW 1990

1. Refers to the Nevada Division of Wildlife.
2. Refers to the U.S. Fish and Wildlife Service

TABLE B.20 cont'd: Total Mercury in Muscle Tissue of White Bass Collected from the Carson River System							
General Location	**Sampling Location**	**Sample Size**	**Average Weight (grams)**	**Average Length (inches)**	**Hg Range (mg/kg, wet weight)**	**Average Hg (mg/kg, wet weight)**	**Data Source**
Carson River Below Lahontan Dam	Sheckler Reservoir	3	--	8.10	0.56 - 0.74	0.67	Cooper et al. 1985
	Below Sagouspe Reservoir	1	--	7.10	--	1.10	Cooper et al. 1985
	Carson Sink at Carson River	2	--	11.40	1.29 - 1.84	1.56	Cooper et al. 1985
	Carson Sink at Humboldt River	1	--	9.90	--	0.85	Cooper et al. 1985
	S-Line Reservoir	2	--	6.80	0.29 - 3.39	1.84	Cooper et al. 1985
	Twin Lake	3	--	10.40	0.70 - 0.90	0.74	Cooper et al. 1985
Stillwater	Lead Lake	1	--	10.00	--	0.21	Cooper et al. 1985
Indian Lakes	Likes Lake	5	465.00	11.14	--	1.20	USFWS[2] 1993
	Papoose Lake	2	1311.00	14.76	--	1.90	USFWS 1993
	Big Indian Lake	2	1271.00	15.04	--	2.20	USFWS 1993
	Big Indian Lake	1	--	13.00	--	1.90	Cooper et al. 1985
	Cottonwood Lake	1	1090.00	14.80	--	2.70	USFWS 1993

1. Refers to the Nevada Division of Wildlife.
2. Refers to the U.S. Fish and Wildlife Service

TABLE B.20 cont'd: Total Mercury in Muscle Tissue of Walleye Collected from the Carson River System						
Sampling Location	**Sample Size**	**Average Weight (grams)**	**Average Length (inches)**	**Hg Range (mg/kg, wet weight)**	**Average Hg (mg/kg, wet weight)**	**Data Source**
Lahontan Reservoir	9	–	12.40	0.54 - 2.07	0.97	NDOW[1] 1984
	2	--	16.80	1.54 - 2.79	2.16	NDOW 1985
	20	1672	19.50	1.85 - 5.32	3.10	NDOW 1986
	7	--	15.80	0.69 - 3.22	2.10	NDOW 1987
	20	1785	19.80	0.72 - 4.45	2.60	NDOW 1988
	11	1029	16.40	1.37 - 5.10	2.90	NDOW 1989
	10	–	20.10	1.32 - 4.37	2.70	NDOW 1990
	9	–	12.40	0.54 - 2.07	0.97	Cooper et al. 1985
Below Carson Diversion	2	–	16.80	1.54 - 2.79	2.16	Cooper et al. 1985

1. Refers to the Nevada Division of Wildlife

TABLE B.21: Total Mercury in Muscle Tissue of Shoveler Ducks from the Carson River System								
General Location	Sampling Location	Sampling Date	Sample Size	Total Hg (mg/kg, dry weight)		Percent Moisture[1]	Mean Total Mercury (mg/kg wet wt.)[2]	Source
				Range	Mean			
Carson Lake	Not specified	8/17/87	1	-	1.40	74.20	0.36	Hoffman et. al., 1990
	Not specified	10/17/87	10	2.10 - 55.70	21.29	72.58	5.83	Rowe et. al., 1991
	Sprig Pond	8/17/89	5	1.10 - 12.00	4.88	73.24	1.31	Rowe et. al., 1991
	Sprig Pond	8/21/89	5	1.70 - 4.90	3.20	74.16	0.83	Rowe et. al., 1991
	Sprig Pond	10/14/89	10	0.86 - 36.00	10.22	73.11	2.75	Rowe et. al., 1991
Stillwater	Lead Lake	8/25/87	1	-	0.12	72.50	0.03	Hoffman et. al., 1990
		8/26/87	2	1.20 - 3.30	2.25	72.65	0.62	Hoffman et. al., 1990
		8/28/87	1	-	1.60	73.60	0.42	Hoffman et. al., 1990
	Tule Lake	8/27/87	1	-	0.50	72.40	0.14	Hoffman et. al., 1990
	Not specified	10/17/87	10	0.58 - 19.00	3.34	73.34	0.89	Rowe et. al., 1991

1. For sample sizes greater than 1, the percent moisture value is the arithmetic mean of the values reported in the respective reference.
2. Mean wet weight concentrations are calculated with the arithmetic mean of the total mercury and moisture content values presented in this table.

TABLE B.22: Total Mercury in Muscle Tissue of Mallard Ducks from the Carson River System								
General Location	Sampling Location	Sampling Date	Sample Size	Total Hg (mg/kg, dry weight)		Percent Moisture[1]	Mean Total Mercury (mg/kg wet wt.)[2]	Source
				Range	Mean			
Carson Lake	Island Unit	7/30/87	1	--	4.50	79.30	0.93	Hoffman et. al., 1990
	Sprig Pond	8/6/87	3	4.00 - 7.93	5.41	74.83	1.36	Hoffman et. al., 1990
	East Lee Drain	8/6/87	1	--	0.34	74.90	0.09	Hoffman et. al., 1990
	West Lee Drain	8/10/87	1	--	6.22	76.30	1.47	Hoffman et. a., 1990
	Not specified	10/17/87	10	0.13 - 4.20	1.86	73.79	0.49	Rowe et. al., 1991
Stillwater	Lead Lake	8/27/87	1	--	1.90	72.80	0.52	Hoffman et. al., 1990
		8/28/87	1	--	2.60	73.10	0.70	Hoffman et. al., 1990
		9/1/87	1	--	0.13	73.30	0.04	Hoffman et. al., 1990
	Tule Lake	8/26/87	1	--	0.34	73.70	0.09	Hoffman et. al., 1990
	Not specified	10/18/87	10	0.05 - 4.40	1.15	71.94	0.32	Rowe et. al., 1991

1. For sample sizes greater than 1, the percent moisture value is the arithmetic mean of the values reported in the respective reference.
2. Mean wet weight concentrations are calculated with the arithmetic mean of the total mercury and moisture content values presented in this table.

TABLE B.23: Total Mercury in Muscle Tissue of Green Wing Teal from the Carson River System								
General Location	Sampling Location	Sampling Date	Sample Size	Total Hg (mg/kg, dry weight)		Percent Moisture[1]	Mean Total Mercury (mg/kg wet wt.)[2]	Source
				Range	Mean			
Carson Lake	Sprig Pond	10/14/89	10	0.18 - 13.00	2.70	73.62	0.71	Rowe et. al., 1991

1. For sample sizes greater than 1, the percent moisture value is the arithmetic mean of the values reported in the respective reference.
2. Mean wet weight concentrations are calculated with the arithmetic mean of the total mercury and moisture content values presented in this table.

Appendix C

APPENDIX C: PARTICULATE EMISSION FACTOR EQUATION

$$PEF\ (m^3/kg) = \frac{(LS \times DH \times 3600 s/hr)}{A} \times \frac{1000\ g/kg}{(0.36 \times (1-G) \times (U_m/U_t)^3 \times F(x))}$$

Parameter	Definition	Default
PEF	particulate emission factor (m^3/kg)	4.63×10^9 m^3/kg
LS	width of contaminated area (m)	45 meters
V	wind speed in mixing zone (m/s)	2.25 m/s
DH	diffusion height	2 meters
A	area of contamination (m^2)	2025 m^2
0.36	respirable fraction (g/m^2-hr)	0.36 g/m^2-hr
G	fraction of vegetative cover (unitless)	0
U_m	mean annual wind speed (m/s)	4.5 m/s
U_t	equivalent threshold value of wind speed	12.8 m/s
F(x)	function dependent on U_m/U_t (unitless)	0.0497 (determined using Cowherd, 1985)

Appendix D

APPENDIX D: POTENTIALLY COMPLETE EXPOSURE PATHWAYS

TABLE D.1: Potentially Complete Exposure Pathways for Populations of Concern in Lyon County									
Population of Concern	*Dayton*			*Silver City*			*Silver Springs*		
Exposure Type/Area of Concern	**Res[1]**	**Occ[2]**	**Rec[3]**	**Res**	**Occ**	**Rec**	**Res**	**Occ**	**Rec**
Soil Ingestion/Floodplain AL[4]	X	X	X			X			X
Produce Ingestion/Floodplain AL	X			X			X		
Dust Inhalation/Floodplain AL	X	X	X			X	X	X	X
Vapor Inhalation/Floodplain AL	X	X	X			X	X		X
Soil Ingestion/Floodplain BL[5]			X			X			X
Produce Ingestion/Floodplain BL	X			X			X		
Dust Inhalation/Floodplain BL			X			X			X
Vapor Inhalation/Floodplain BL			X			X			X
Soil Ingestion/Millsite	X	X	X	X	X	X			X
Produce Ingestion/Millsite	X			X					X
Dust Inhalation/Millsite	X	X	X	X	X	X			X
Vapor Inhalation/Millsite	X	X	X	X	X	X			X
Soil Ingestion/Alluvial[6]	X	X	X						
Produce Ingestion/Alluvial	X								
Dust Inhalat./Alluvial	X	X	X						
Vapor Inahalat./Alluvial	X	X	X						
Soil Ingestion/Sixmile Canyon[7]	X	X	X	X	X	X			
Dust Inhalation/Sixmile Canyon	X	X	X	X	X	X			
Vapor Inhalation/Sixmile Canyon	X	X	X	X	X	X			

TABLE D.1 cont'd: Potentially Complete Exposure Pathways for Populations of Concern in Lyon County									
Population of Concern	Dayton			Silver City			Silver Springs		
Exposure Type/Area of Concern	Res	Occ	Rec	Res	Occ	Rec	Res	Occ	Rec
Soil Ingestion/Gold Canyon		X	X	X	X	X		X	
Dust Inhalation/Gold Canyon		X	X	X	X	X		X	
Vapor Inhalation/Gold Canyon		X	X	X	X	X		X	
Fish Ingestion/Carson River AL	X		X	X		X	X		X
Soil Ingestion/Lahontan			X			X			X
Fish Ingestion/Lahontan	X		X	X		X	X		X
Soil Ingestion/Washoe[8]			X			X			X
Dust Inhalation/Washoe			X			X			X
Vapor Inhalation/Washoe			X			X			X
Fish Ingestion/Washoe	X		X	X		X	X		X
Fish Ingestion/Carson River BL	X		X	X		X	X		X
Waterfowl Ingestion/Carson Lake	X		X	X		X	X		X
Soil Ingestion/Indian Lake	X	X	X						
Fish Ingestion/Indian Lake	X	X	X	X	X	X			
Fish Ingestion/Stillwater	X	X	X	X	X	X			
Waterfowl Ingestion/Stillwater	X	X	X	X	X	X			

TABLE D.1 cont'd: Potentially Complete Exposure Pathways for Populations of Concern in Lyon County									
Population of Concern	**Dayton**			**Silver City**			**Silver Springs**		
Exposure Type/Area of Concern	**Res**	**Occ**	**Rec**	**Res**	**Occ**	**Rec**	**Res**	**Occ**	**Rec**
TOTAL	25	19	31	20	12	27	19	9	34

1. Abbreviation for Residential Land Use.
2. Abbreviation for Occupational Land Use.
3. Abbreviation for Recreational Land Use.
4. Abbreviation for Above Lahontan Dam.
5. Abbreviation for Below Lahontan Dam.
6. Abbreviation for Alluvial Fan below Sixmile Canyon.
7. Refers to both Sixmile and Sevenmile Canyon.
8. Abbreviation for Little and Big Washoe Lake Recreation areas.

TABLE D.2: Potentially Complete Exposure Pathways for Populations of Concern in Storey County									
Population of Concern	**Virginia City**			**Mark Twain**			**Gold Hill**		
Exposure Type/Area of Concern	**Res[1]**	**Occ[2]**	**Rec[3]**	**Res**	**Occ**	**Rec**	**Res**	**Occ**	**Rec**
Soil Ingestion/Floodplain AL[4]			X			X			X
Produce Ingestion/Floodplain AL	X			X			X		
Dust Inhalation/Floodplain AL			X			X			X
Vapor Inhalation/Floodplain AL			X			X			X
Soil Ingestion/Floodplain BL[5]			X			X			X
Produce Ingestion/Floodplain BL	X			X			X		
Dust Inhalation/Floodplain BL			X			X			X
Vapor Inhalation/Floodplain BL			X			X			X
Soil Ingestion/Millsite	X	X	X			X	X	X	X
Produce Ingestion/Millsite	X			X			X		
Dust Inhalation/Millsite	X	X	X			X	X	X	X
Vapor Inhalation/Millsite	X	X	X			X	X	X	X
Soil Ingestion/Alluvial[6]			X	X	X	X			X
Produce Ingestion/Alluvial				X					
Dust Inhalat./Alluvial			X	X	X	X			X
Vapor Inahalat./Alluvial			X	X	X	X			X
Soil Ingestion/Sixmile Canyon[7]	X	X	X			X			X
Dust Inhalation/Sixmile Canyon	X	X	X			X			X
Vapor Inhalation/Sixmile Canyon	X	X	X			X			X

TABLE D.2 cont'd: Potentially Complete Exposure Pathways for Populations of Concern in Storey County									
Population of Concern	**Virginia City**			**Mark Twain**			**Gold Hill**		
Exposure Type/Area of Concern	**Res**	**Occ**	**Rec**	**Res**	**Occ**	**Rec**	**Res**	**Occ**	**Rec**
Soil Ingestion/Gold Canyon			X			X	X	X	X
Dust Inhalation/Gold Canyon			X			X	X	X	X
Vapor Inhalation/Gold Canyon			X			X	X	X	X
Fish Ingestion/Carson River AL	X		X	X		X	X		X
Soil Ingestion/Lahontan			X			X			X
Fish Ingestion/Lahontan	X		X	X		X	X		X
Soil Ingestion/Washoe[8]			X			X			X
Dust Inhalation/Washoe			X			X			X
Vapor Inhalation/Washoe			X			X			X
Fish Ingestion/Washoe	X		X	X		X	X		X
Fish Ingestion/Carson River BL	X		X	X		X	X		X
Waterfowl Ingestion/Carson Lake	X		X	X		X	X		X
Soil Ingestion/Indian Lakes			X			X			X
Fish Ingestion/Indian Lakes	X		X	X		X	X		X
Waterfowl Ingestion/Stillwater	X		X	X		X	X		X

TABLE D.2 cont'd: Potentially Complete Exposure Pathways for Populations of Concern in Storey County									
Population of Concern	Virginia City			Mark Twain			Gold Hill		
Exposure Type/Area of Concern	Res	Occ	Rec	Res	Occ	Rec	Res	Occ	Rec
TOTAL	16	6	30	14	3	30	16	6	30

1. Abbreviation for Residential Land Use.
2. Abbreviation for Occupational Land Use.
3. Abbreviation for Recreational Land Use.
4. Abbreviation for Above Lahontan Dam.
5. Abbreviation for Below Lahontan Dam.
6. Abbreviation for the Alluvial Fan below Sixmile Canyon
7. Refers to both Six Mile Canyon and Sevenmile Canyon.
8. Abbreviation for Little and Big Washoe Lake.

TABLE D.3: Potentially Complete Exposure Pathways for Populations of Concern in Churchill Co. and South Valley, Washoe Co.									
Population of Concern	Fallon			Fallon Paiute,Shoshone Res.			New Washoe City		
Exposure Type/Area of Concern	Res[1]	Occ[2]	Rec[3]	Res	Occ	Rec	Res	Occ	Rec
Soil Ingestion/Floodplain AL[4]			X			X			X
Produce Ingestion/Floodplain AL							X		
Dust Inhalation/Floodplain AL			X			X			X
Vapor Inhalation/Floodplain AL			X			X			X
Soil Ingestion/Floodplain BL[5]	X	X	X	X	X	X			X
Produce Ingestion/Floodplain BL	X	X	X	X	X	X	X		
Dust Inhalation/Floodplain BL	X	X	X	X	X	X			X
Vapor Inhalation/Floodplain BL	X	X	X	X	X	X			X
Soil Ingestion/Millsite			X			X	X	X	X
Produce Ingestion/Millsite							X		
Dust Inhalation/Millsite			X			X	X	X	X
Vapor Inhalation/Millsite			X			X	X	X	X
Soil Ingestion/Alluvial[6]			X			X			X
Produce Ingestion/Alluvial							X		
Dust Inhalation/Alluvial			X			X			X
Vapor Inahalation/Alluvial			X			X			X
Soil Ingestion/Sixmile Canyon[7]	X	X	X						
Dust Inhalation/Sixmile Canyon	X	X	X						
Vapor Inhalation/Sixmile Canyon	X	X	X						

TABLE D.3 cont'd: POTENTIALLY COMPLETE EXPOSURE PATHWAYS IN CHURCHILL COUNTY & WASHOE VALLEY

Population of Concern	Fallon			Fallon Paiute,Shoshone Res.			New Washoe City		
Exposure Type/Area of Concern	Res	Occ	Rec	Res	Occ	Rec	Res	Occ	Rec
Soil Ingestion/Gold Canyon			X			X			X
Dust Inhalation/Gold Canyon			X			X			X
Vapor Inhalation/Gold Canyon			X			X			X
Fish Ingestion/Carson AL	X		X	X		X	X		X
Soil Ingestion/Lahontan			X			X			X
Fish Ingestion/Lahontan	X		X	X		X	X		X
Soil Ingestion/Washoe[8]			X			X			X
Dust Inhalation/Washoe			X			X	X	X	X
Vapor Inhalation/Washoe			X			X	X	X	X
Fish Ingestion/Washoe	X		X	X		X	X		X
Fish Ingestion/Carson River BL	X		X	X		X	X		X
Waterfowl Ingestion/Carson Lake	X		X	X		X	X		X
Soil Ingestion/Indian Lakes	X	X	X						
Fish Ingestion/Indian Lakes	X	X	X	X	X	X			
Waterfowl Ingestion/Stillwater	X	X	X	X	X	X			

TABLE D.3 cont'd: POTENTIALLY COMPLETE EXPOSURE PATHWAYS IN CHURCHILL COUNTY & WASHOE VALLEY									
Population of Concern	Fallon			Fallon Palute, Shoshone Res.			New Washoe City		
Exposure Type/Area of Concern	Res	Occ	Rec	Res	Occ	Rec	Res	Occ	Rec
TOTAL	15	10	31	11	7	27	14	5	24

1. Abbreviation for Residential Land Use.
2. Abbreviation for Occupational Land Use.
3. Abbreviation for Recreational Land Use.
4. Abbreviation for Above Lahontan Dam.
5. Abbreviation for Below Lahontan Dam.
6. Abbreviation for Alluvial Fan below Six Mile Canyon.
7. Refers to both Sixmile and Sevenmile Canyon.
8. Abbreviation for Little and Big Washoe Lake.

Appendix E

APPENDIX E: CHRONIC DAILY INTAKE EQUATIONS AND PARAMETERS

Ingestion of Chemicals in Soil:

$$\text{Intake (mg/kg-day)} = \frac{CS \times IR \times 10\ E\text{-}6\ kg/mg \times FI \times EF \times ED}{BW \times AT}$$

Inhalation of Airborne & Vapor Phase Chemicals:

$$\text{Intake (mg/kg-day)} = \frac{CA \times IR \times ET \times ED}{BW \times AT}$$

Ingestion of Contaminated Fruit and Vegetables:

$$\text{Intake (mg/kg-day} = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

Ingestion of Contaminated Fish and Waterfowl:

$$\text{Intake (mg/kg-day)} = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

Where:
CS = Concentration in soil (mg/kg)
CA = Concentration in air (mg/m^3)
CF = Concentration in food (mg/kg)
IR = Ingestion rate (see Tables E.1 - E.7)
FI = Fraction Ingested (= 1.00)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (ED x 365 days/year)

TABLE E.1: Parameters for Ingestion						
Parameter	Typical Estimate		High-End Estimate			
	Adult Resident	School Age Child[a] Recreation	Adult Resident	School Age Child Resident	Young Child[b] Resident	School Age Child Recreation
IR = Ingestion Rate (mg/day)[c]	50	50	100	100	200	50
EF = Exposure Frequency (days/year)	350	5[d]	350	350	350	104[e]
ED = Exposure Duration (years)	9	12	30	12	6	12
BW = Body Weight (kg)	70	43	70	43	15	43
AT = Averaging Time (days) Non-cancer	3285	4380	10950	4380	2190	4380
AT = Averaging Time (days) Cancer	25550	25550	25550	25550	25550	25550

a. School age child = 7 - 18 years of age
b. Young child = 1 to 6 years of age
c. EPA 1990
d. EPA 1992
e. Assumes 2 days per week, 6 months per year.

TABLE E.2: Parameters for Inhalation						
Parameter	Typical Estimate		High-End Estimate			
	Adult Resident	School Age Child[a] Recreation	Adult Resident	School Age Child Resident	Young Child[b] Resident	School Age Child Recreation
IR = Inhalation Rate (m^3/hr)[c]	0.83	4.2	0.83	0.83	0.66	4.2
ET = Exposure Time (hr/day)	24	3	24	24	24	3
EF = Exposure Frequency (days/year)	350	5[d]	350	350	350	104[e]
ED = Exposure Duration (years)	9	12	30	12	6	12
BW = Body Weight (kg)	70	43	70	43	15	43
AT = Averaging Time (days) Non-cancer	3285	4380	10950	4380	2190	4380
AT = Averaging Time (days) Cancer	25550	25550	25550	25550	25550	25550

a. School age child = 7 - 18 years of age
b. Young child = 1 to 6 years of age
c. EPA 1990
d. EPA 1992
e. Assumes 2 days per week, 6 months per year.

TABLE E.3: Typical Paramters for Ingestion of Locally-Grown Vegetables				
Parameter		Receptor and Land Use		
		Young Child[a] Resident	School Age Child[b] Resident	Adult Resident
IR = Ingestion Rate (grams/day)[c]	Root Vegetables	39	59	87
	Leafy Vegetables	15	22	32
	Above Ground Protected Vegetables	16	23	34
	Above Ground Exposed Vegetables	34	52	75
	Fruits	138	155	142
FI = Fraction of Vegetable Diet Consisting of Local Produce[d]		0.25	0.25	0.25
EF = Exposure Frequency (days/year)		350	350	350
ED = Exposure Duration (years)		6	9	9
BW = Body Weight (kg)		15	31	70
AT = Averaging Time (days)		2190	3285	3285

a. Young child = 1 to 6 years of age.
b. School-age child = 7 to 18 years of age.
c. EPA 1990
d. EPA 1990

TABLE E.4: High-End Parameters for Ingestion of Locally-Grown Vegetables				
Parameter		Receptor and Land Use		
		Young Child[a] Resident	School Age Child[b] Resident	Adult Resident
IR = Ingestion Rate (grams/day)[c]	Root Vegetables	39	59	87
	Leafy Vegetables	15	22	32
	Above Ground Protected Vegetables	16	23	34
	Above Ground Exposed Vegetables	34	52	75
	Fruits	138	155	142
FI = Fraction of Vegetable Diet Consisting of Local Produce[d]		0.4	0.4	0.4
EF = Exposure Frequency (days/year)		350	350	350
ED = Exposure Duration (years)		6	9	30
BW = Body Weight (kg)		15	31	70
AT = Averaging Time (days)		2190	3285	10950

a. Young child = 1 to 6 years of age.
b. School-age child = 7 to 18 years of age.
c. EPA 1990
d. EPA 1990

TABLE E.5: Angler Statistics for Churchill County Compiled by the Nevada Division of Wildlife						
Year	Total Anglers[1]	Total Fish[2]	Total Days[3]	Days/Angler	Fish/Angler	Fish/Day
1981	763	11754	3171	4.16	15.40	3.71
1982	575	3802	3380	5.88	6.61	1.12
1983	1038	9903	7140	6.88	9.54	1.39
1984	868	8667	4109	4.73	9.99	2.11
1985	720	11224	5516	7.66	15.59	2.03
1986	509	9893	4786	9.40	19.44	2.07
1987	382	5493	1747	4.57	14.38	3.14
1988	204	2872	1175	5.76	14.08	2.44
1989	290	2217	549	1.89	7.64	4.04
1990	147	81	348	2.37	0.55	0.23
Average	550	6591	3192	5.33	11.32	2.23

1. Total anglers refers to the total number of fishing licenses issued by NDOW including licenses obtained by the Fallon Reservation.
2. Total fish refers to the total number of fish caught and reported.
3. Total days refers to the total number of days permitted for fishing with all of the licenses issued.

TABLE E.6: Exposure Parameters for Consumption of Fish from the Carson River System			
Parameter	Typical	High-end	
	Adult Recreation	Adult Recreation	Subsistence Fisherman
IR = Ingestion Rate (grams/day)[a]	24	45	140[b]
EF = Exposure Frequency (days/year)	350	350	350
ED = Exposure Duration (years)	9	30	30
BW = Body Weight (kg)	70	70	70
AT = Averaging Time (days)	3285	10950	10950

a. Derived from statistics developed by the Nevada Department of Wildlife
b. EPA 1990

TABLE E.7: Exposure Parameters for Consumption of Waterfowl from the Carson River System		
Parameter	Typical	High-end
	Adult Recreation	Adult Recreation
IR = Ingestion Rate (grams/day)[a]	12	12
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	9	30
BW = Body Weight (kg)	70	70
AT = Averaging Time (days)	3285	10950

a. Derived from statistics developed by the Nevada Department of Wildlife
b. EPA 1990

Appendix F

APPENDIX F: INPUT PARAMETERS FOR UBK LEAD MODEL

BSORPTION METHODOLOGY: Non-Linear Active-Passive

IR CONCENTRATION: 0.200 ug Pb/m3 DEFAULT
Indoor AIR Pb Conc: 30.0 percent of outdoor.
Other AIR Parameters:

Age	Time Outdoors (hr)	Vent. Rate (m3/day)	Lung Abs. (%)
0-1	1.0	2.0	32.0
1-2	2.0	3.0	32.0
2-3	3.0	5.0	32.0
3-4	4.0	5.0	32.0
4-5	4.0	5.0	32.0
5-6	4.0	7.0	32.0
6-7	4.0	7.0	32.0

IET: DEFAULT

RINKING WATER Conc: 15.00 ug Pb/L
WATER Consumption: DEFAULT

OIL & DUST:
Soil: constant conc.
ust: constant conc.

Age	Soil (ug Pb/g)	House Dust (ug Pb/g)
0-1	298.7	298.7
1-2	298.7	298.7
2-3	298.7	298.7
3-4	298.7	298.7
4-5	298.7	298.7
5-6	298.7	298.7
6-7	298.7	298.7

Additional Dust Sources: None DEFAULT

AINT Intake: 0.00 ug Pb/day DEFAULT

ATERNAL CONTRIBUTION: Infant Model
Maternal Blood Conc: 7.50 ug Pb/dL

Appendix G

APPENDIX G: DERIVATION OF SITE-SPECIFIC CLEANUP GOALS FOR MERCURY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

Memorandum:

Date: December 1, 1994

Subject: Issue Paper for Determination of a Site-Specific Cleanup Goal for Mercury in Residential Soils

From: **Stanford Smucker, Ph.D.**
Regional Toxicologist (H-9-3)

To: **Sean Hogan**
Remedial Project Manager (H-6-3)

A residential cleanup goal of **80 ppm Mercury** in soil is recommended for the Carson River site based on information obtained in the baseline comprehensive risk assessment. This soil cleanup goal identifies a soil level that would create a dose for a child (age 1-6) equivalent to U.S. EPA's oral reference dose (RfD) for inorganic mercury. The reason for the focus on children is that children engage in activities that tend to promote soil ingestion.

This technical memorandum documents the assumptions and supporting data used in the determination of a cleanup goal for your site. Mercury speciation by EPA's Environmental Monitoring Systems Laboratory - Las Vegas (EPA, 1994) indicated that 10% or less of the total mercury in soils was present as bioavailable species (i.e. water- or acid-soluble forms) with the predominant forms being relatively unavailable for intestinal absorption (i.e. elemental mercury and mercuric sulfide). Attachment A summarizes oral absorption information for the different species of mercury in soils. This information was used to adjust mercury exposure through incidental ingestion.

cc: File
Dave Jones (H-6)
Tom Kremer (H-6-3)

Uncertainties

There are site-specific uncertainties associated with the recommended cleanup goal for mercury. Sources of uncertainty include assumptions regarding exposure scenarios/pathways, use of mercury speciation data that is based on new methods under development, and use of oral absorption and toxicity data that are based on animal studies.

Human behavior patterns can strongly affect exposure results. Based on the limitations of our knowledge, the values for the exposure duration and frequency for the pathways considered are intended to be reasonable upperbound estimates. For example, the soil ingestion scenario assumes that a child will be ingesting 200 mg/day for a period of 6 years. The exposure values obtained do not account for children with pica behavior (i.e. children that deliberately ingest dirt). Exposure estimates that reflect this type of behavior could be considerably higher. However, these types of exposures are expected to be episodic and not continual over 6 years.

An indirect method for speciating mercury in soils was applied at the site. While the results are, for the most part, comparable to a second method used by Oak Ridge Research Institute (Revis et al. 1990), there was an inconsistency in the two methods with respect to the determination of mercuric sulfide (HgS) and elemental mercury (Hg^o). This discrepancy had not been resolved at the time of this memorandum so that the more health-protective assumption that these forms are HgS is assumed in the risk assessment.

Presently there appear to be a few vegetable gardens located in the affected area within Dayton. Vegetables that are grown in soil containing mercury may take up mercury through the roots. However, soil with mercury is likely to be more dangerous to children who play in it than to children who eat vegetables grown in it. Therefore, the recommended soil goal is based on incidental ingestion of soils and not the consumption of locally grown vegetables. To reduce the amount of mercury exposure from consumption of locally grown vegetables, it is recommended that residents plant fruiting or leafy vegetables, such as lettuce or tomatoes, because they take in less mercury than carrots, beets, and other root crops.

Additional uncertainties in estimating cleanup goals involve toxicological uncertainties related to extrapolating low dose effects from animal studies to humans. In addition, there may be differences in absorption, metabolism, and distribution of heavy metals in the body of animals and humans which can result in a high degree of uncertainty in the soil cleanup goal. As a result, an uncertainty factor of 1000 was incorporated in the estimate. This uncertainty factor may result in a more stringent cleanup level than would be necessary if additional information were available.

Calculation of Soil Goals

In calculating the soil cleanup goal for residential soils, several assumptions were made that include the following:

- The chronic oral RfD for mercury is 3×10^{-4} mg/kg-day;
- Mercury species in soils is 100% inorganic with 90% assumed to be HgS or other relatively inaccessible forms (e.g. Hg^{o}) and 10% assumed to be mercuric chloride ($HgCl_2$) or its biological equivalent (assumed here to include both the water- and acid-soluble fractions);
- The absolute oral absorption of the "reference" species $HgCl_2$ and its biological equivalent is 15% whereas less bioavailable forms are assumed to be equivalent to HgS, conservatively estimated at 3% oral absorption (see Attachment A);
- The relative oral absorption of mercury species, that is relative to the "reference" species $HgCl_2$, is 100% for the water- and acid-soluble fractions (absorption ratio = 15/15) and 20% for less bioavailable forms (absorption ratio = 3/15);

The soil cleanup goal was calculated as follows:

$$C(mg/kg) = \frac{THQxRfDxBWxEDx365d/y}{IRxAbsxEFxED}$$

Where:

THQ is the target hazard quotient set equal to 1;

RfD is the chronic oral reference dose (3×10^{-4}mg/kg-day);

BW is the average body weight of a 1-6 year old child (15 kg);

ED is the exposure duration and averaging time assumed for a young child (6 years);

IR is the oral intake rate (2×10^{-4} kg/day);

Abs. is a site-specific oral absorption factor used to adjust the intake of mercury in soils (0.28) and is based on an assumed ratio of 90% HgS and 10% $HgCl_2$;

EF is the exposure frequency assumed (350 days/year);

ATTACHMENT A

There is considerable variability in the absorption rate of inorganic mercury species from the digestive system; this implies in turn that the health hazard resulting from their ingestion may vary greatly. Appearing below is a summary discussion of the oral absorption of different forms of inorganic mercury as determined in animal studies.

Oral Absorption of Mercury Species in Soil

The oral absorption of different forms of inorganic mercury appears to be a function of the dissolution of the mercury in the GI tract. Assuming this to be true, Hg° is predicted to be least bioavailable and $HgCl_2$ is predicted to be most bioavailable, with HgS falling somewhere in between. As discussed below, this qualitative ranking of bioavailability appears to be borne out in animal studies.

Mercuric Chloride

Although the data are limited, studies suggest that oral absorption of $HgCl_2$, may range from 7 to 15% of an ingested dose (ATSDR 1993) in humans. These estimates are similar to those for mice (estimated at 7 to 20%). There is no evidence to suggest that the absorption for $HgCl_2$ differ qualitatively for rodents and humans and adequate justification exists in the experimental data base for the extrapolation of animal absorption data to humans. Therefore, it is assumed that absorption studies carried out in rodents are applicable to humans.

Elemental Mercury

Elemental mercury is poorly absorbed via the GI tract. Oral absorption of Hg° in the rat is estimated at less than 0.01% (Bornman et al., 1970; U.S. EPA 1988; WHO, 1991), however the data are limited. The low bioavailability of Hg° is also indicated by human exposures to extremely large acute doses where individuals ingested as much as 204 grams of elemental mercury without apparent toxicity (WHO 1991).

Mercuric Sulfide

Several studies have investigated the oral absorption of HgS in mice and rats. These studies were focused mainly on the uptake of HgS relative to that of the reference species, $HgCl_2$. Total absorption could not be measured due to experimental limitations associated with the insolubility of HgS in aqueous solutions.

The highest estimate of the relative uptake of HgS (1/5 ratio sulfide/chloride) can be obtained from a study conducted by Revis et al. (1991). These authors measured intestinal absorption of HgS by comparing intake of Hg in diet to fecal Hg plus Hg in the intestinal lumen. This study was limited in that it did not differentiate between Hg that was never absorbed and versus that which was absorbed and then excreted back into the GI tract. The net result is that the uptake of $HgCl_2$ would likely have been underestimated and, the uptake of HgS relative to $HgCl_2$ would have been overestimated. (HgS, in contrast to HgCl, is insoluble and is likely to remain inert in the GI tract and pass through without significant absorption and excretion back into the GI tract.)

The magnitude of overprediction of the Revis et al. study is suggested in the results from Sin et al. (1983, 1989 and 1990). Sin et al. estimated oral absorption indirectly by measuring tissue ratios of mercury following ingestion of HgS or $HgCl_2$. The bulk of mercury was deposited in the kidney which is also the target organ of interest for inorganic mercury. Based on Sin et al. results (see Table 1), relative absorption of HgS is predicted to be about a factor of 10 lower than what the Revis study suggests (estimates of relative uptake based on kidney ratios range from a 1/30-60 sulfide/chloride).

In the risk assessment for Carson River site, and the derivation of the cleanup goal for soils, the most conservative (health-protective) estimate of uptake was used to adjust the oral absorption value for HgS (i.e. 1/5 sulfide/chloride). This uptake was chosen to represent an upper-bound estimate of relative absorption. Use of this value should not be construed as an endorsement of one experimental method over another but rather, the highest value was chosen because of the uncertainty associated with the limited data.

Table 1. Concentration of Hg^{2+} (ug/g wet tissue) in the liver and kidney of mice after repeated oral doses (mg/kg-day).

Form	Dose	Vehicle	Treatment Duration	Kidney	Liver	Ref.
HgS	1.9	GW[a]	2 weeks	0.22	0.00	Sin et al., 1983
HgS	1.9	GW	8 weeks	0.34	0.01	
$HgCl_2$	1.9	GW	2 weeks	6.5	0.48	
$HgCl_2$	1.9	GW	8 weeks	19.1	3.11	
HgS pills	1.9	GW	2 weeks	0.79	0.15	
HgS pills	1.9	GW	10 weeks	0.30	0.19	
HgS	1.9	GW	7 weeks	0.01[b]	0.00[b]	
$HgCl_2$	1.9	GW	7 weeks	16.7[b]	2.50[b]	
HgS	6	GW	4 days	0.80	0.18	Sin et al., 1989
HgS	324	GW	4 days	1.37	0.44	
$HgCl_2$	6	GW	4 days	41.2	5.84	
HgS	6	GW	10 days	1.34	0.30	Sin et al., 1990
$HgCl_2$	6	GW	10 days	58.04	8.46	

Footnote:
[a]Gavage in water
[b]One week after the last dose

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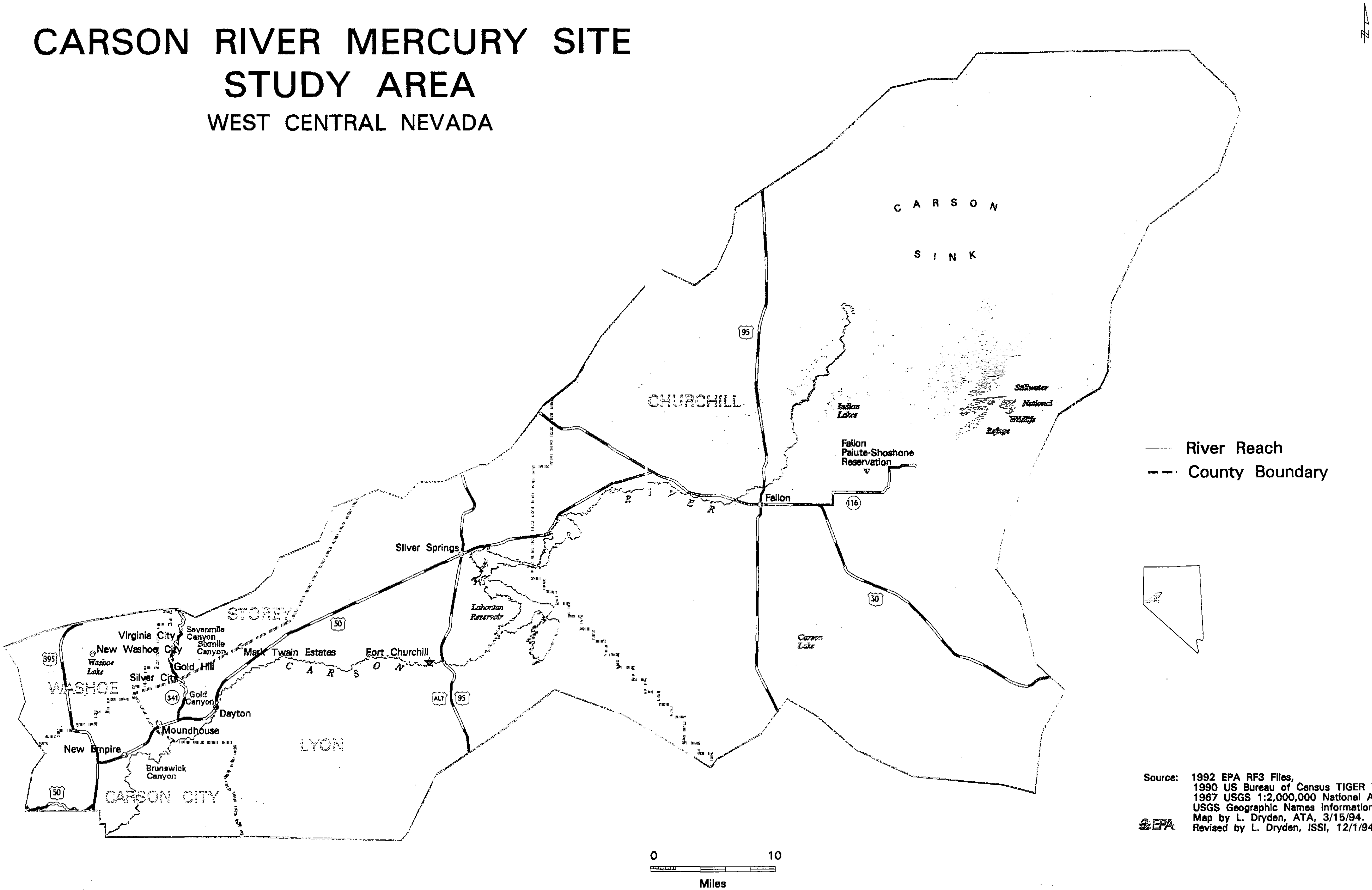
Figures

CARSON RIVER MERCURY SITE
STUDY AREA
WEST CENTRAL NEVADA



Source: 1992 EPA RF3 Files,
1990 US Bureau of Census TIGER Files,
1967 USGS 1:2,000,000 National Atlas Map,
USGS Geographic Names Information System.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

FIGURE 1

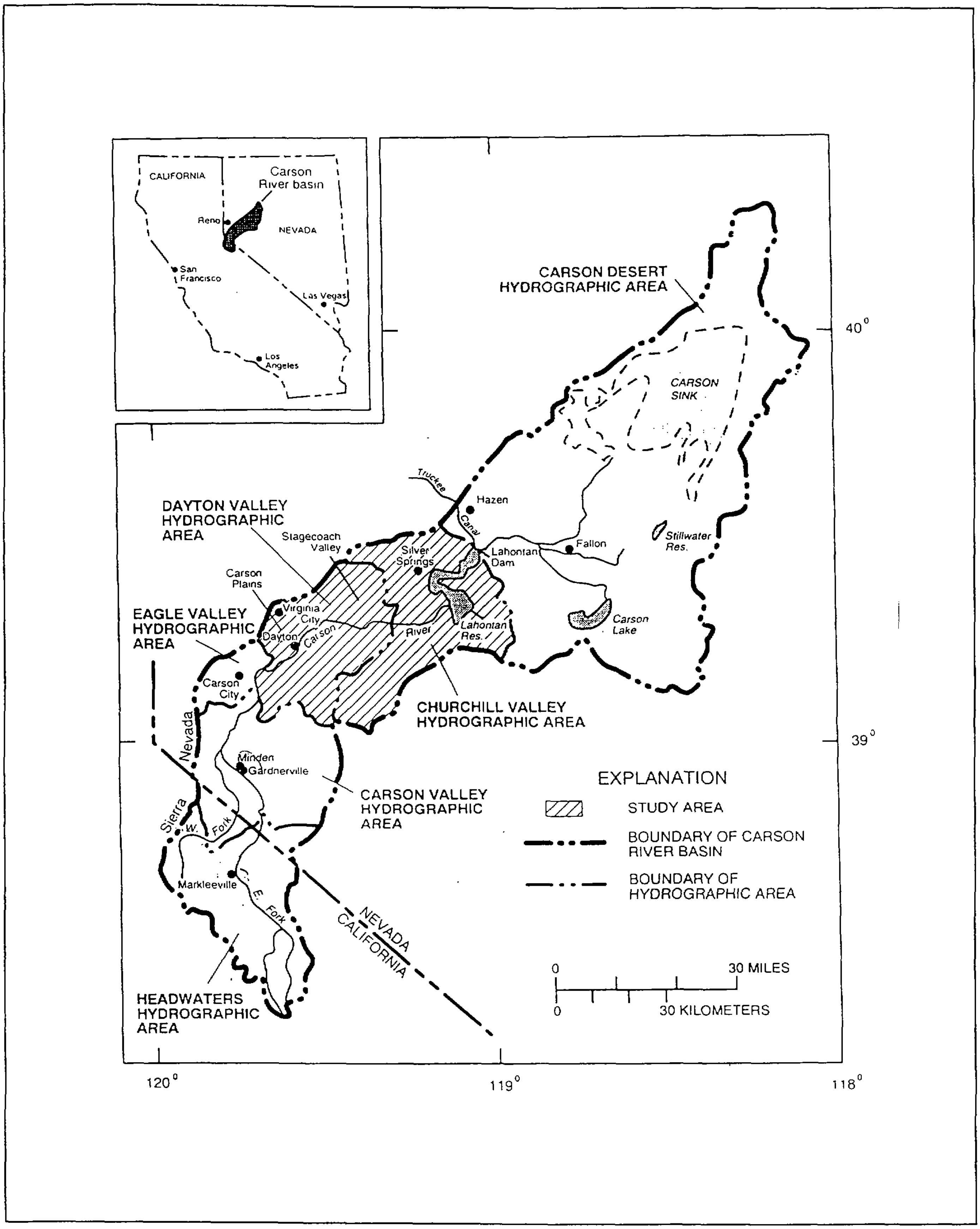
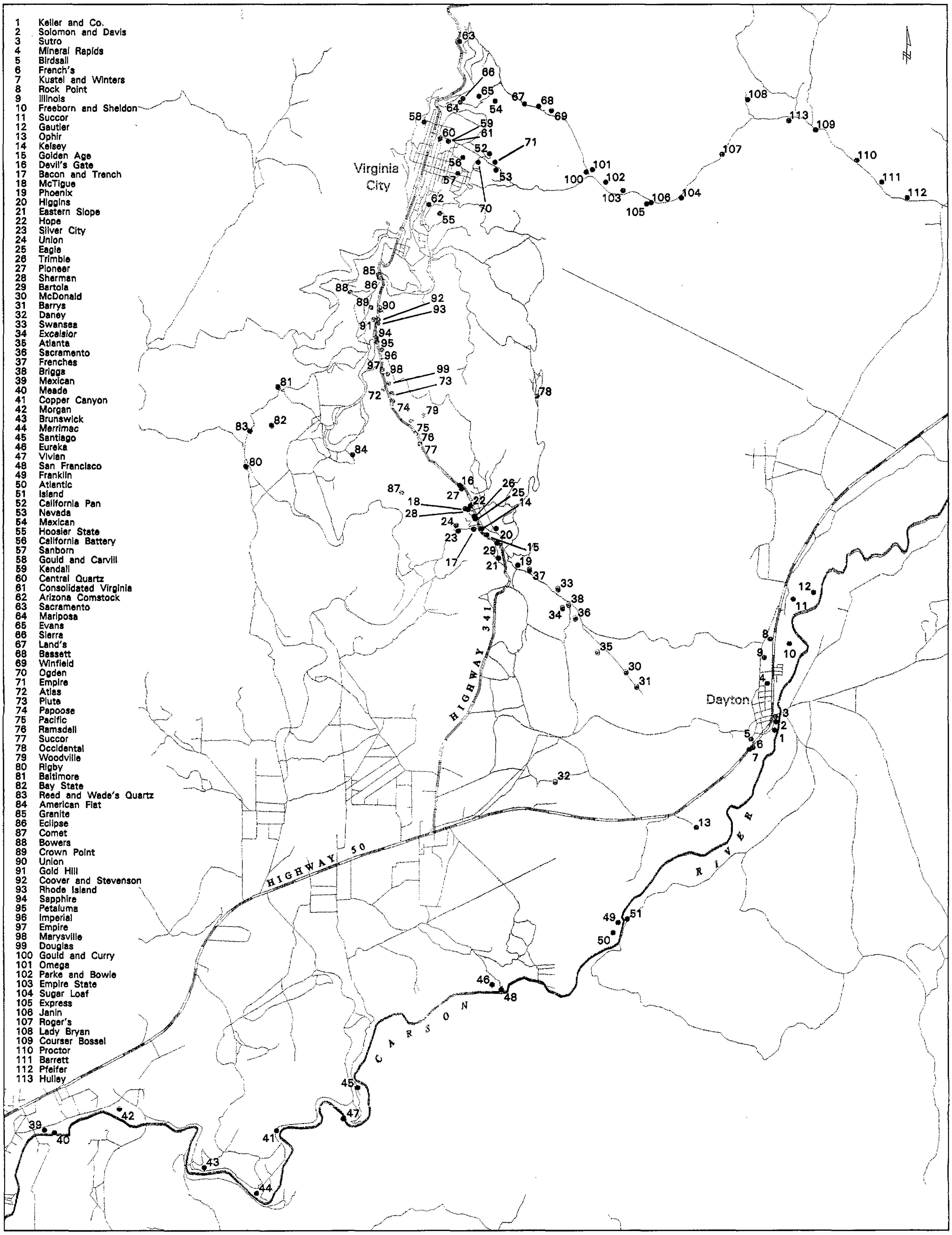
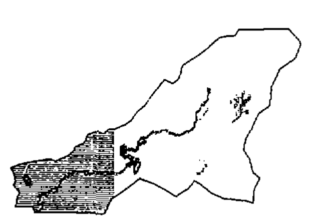


Figure 2: Carson River Basin Hydrographic Areas



HISTORIC COMSTOCK MILL LOCATIONS

STOREY - LYON COUNTY, NEVADA



General Area
- Dayton
- Silver City
- Gold Canyon
- Carson River
- Virginia City
- Gold Hill
- American Flat
- Sixmile Canyon

0 — 2

Miles

Source: Piedmont Engineering, 1993;
1990 US Bureau of Census TIGER Files.
EPA Map by L. Dryden, ATA, 3/15/94.

FIGURE 3

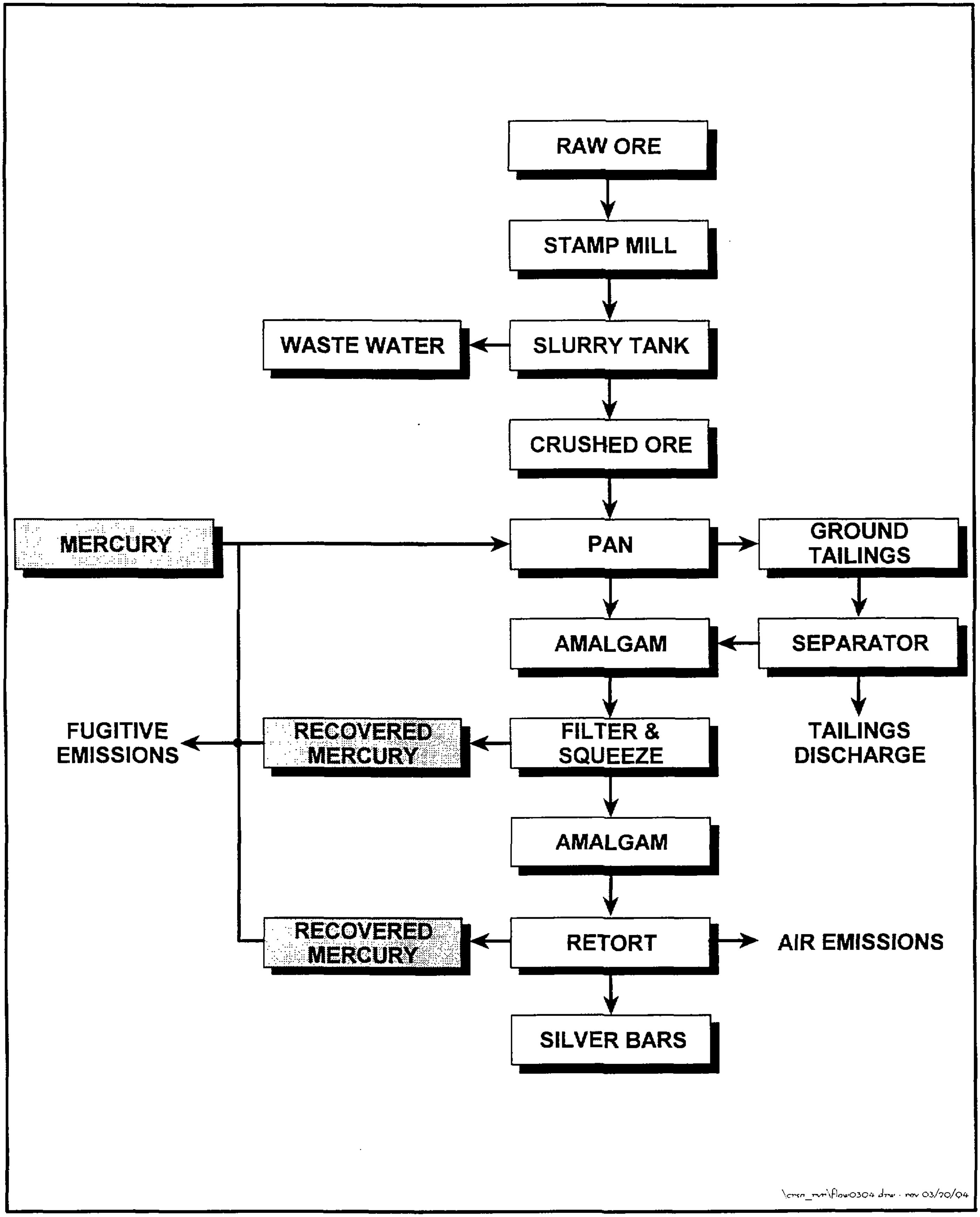
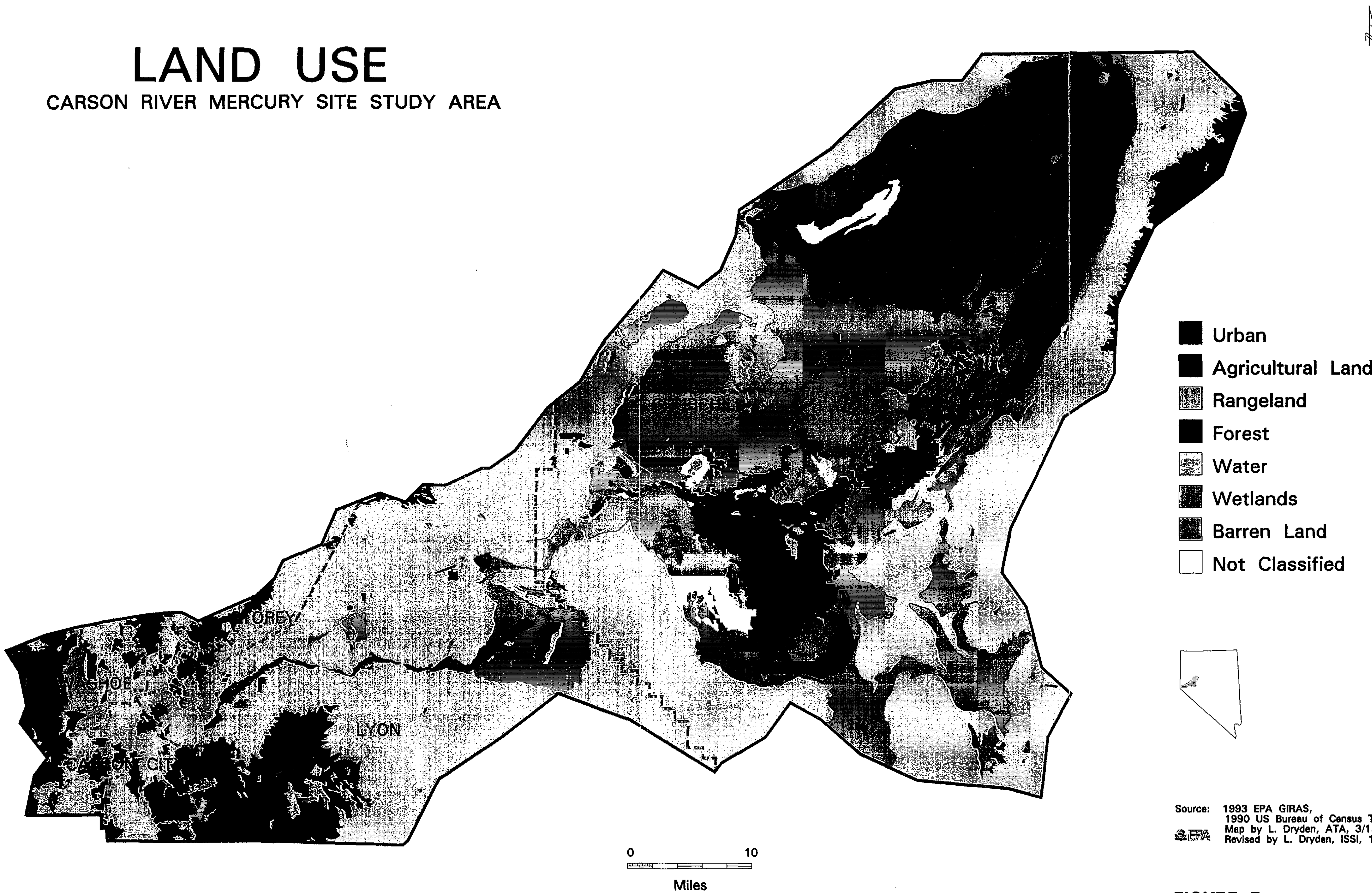


FIGURE 4: WASHOE PROCESS

LAND USE

CARSON RIVER MERCURY SITE STUDY AREA

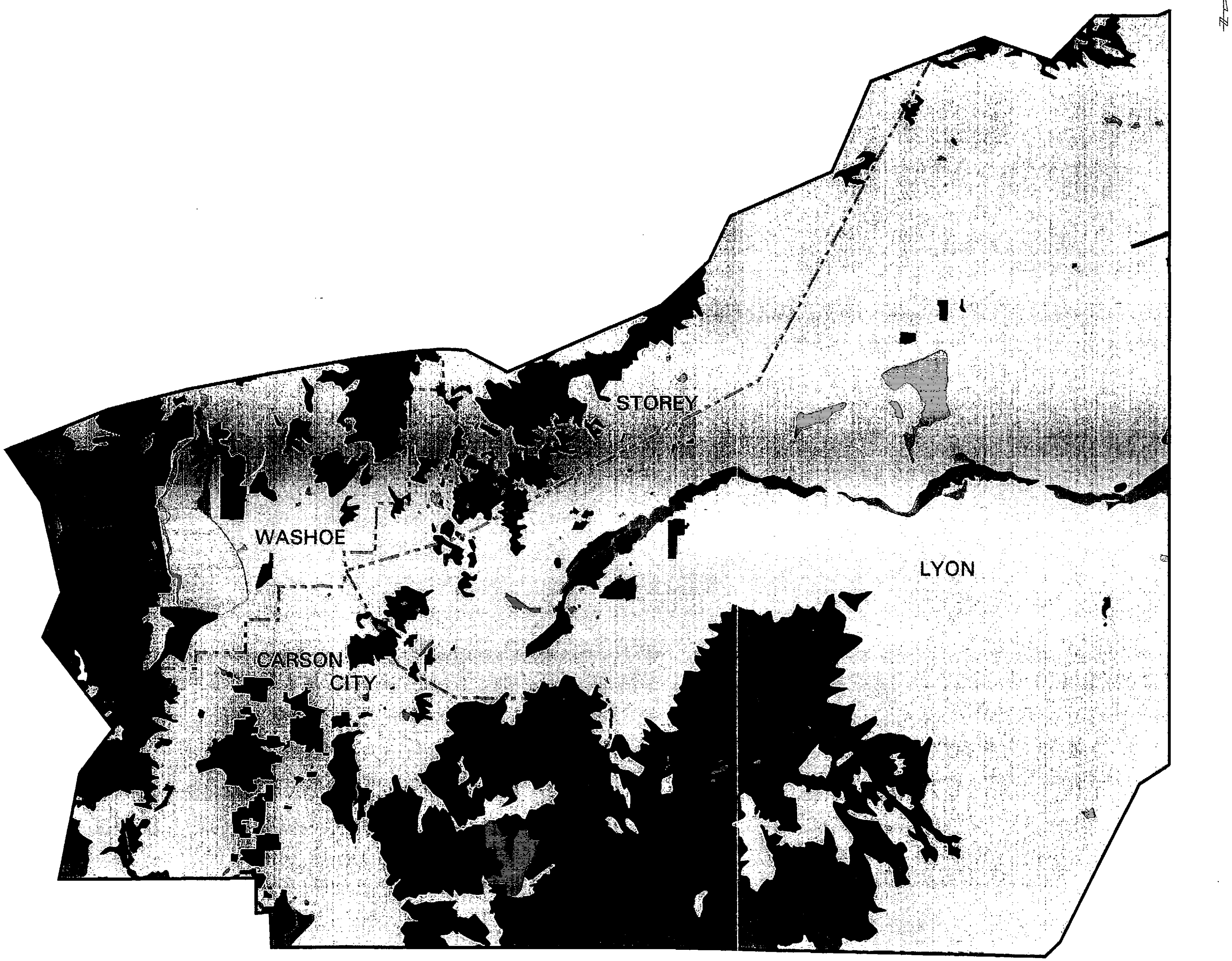


Source: 1993 EPA GIRAS,
1990 US Bureau of Census TIGER Files.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

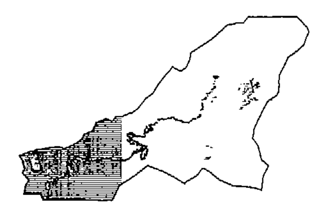
FIGURE 5

LAND USE

CARSON RIVER MERCURY SITE
WESTERN REGION



- Urban
- Agricultural Land
- Rangeland
- Forest
- Water
- Wetlands
- Barren Land
- Not Classified



Source: 1993 EPA GIRAS,
1990 US Bureau of Census TIGER Files.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

0 5
Miles

FIGURE 6

POPULATION DISTRIBUTION

CARSON RIVER MERCURY SITE STUDY AREA

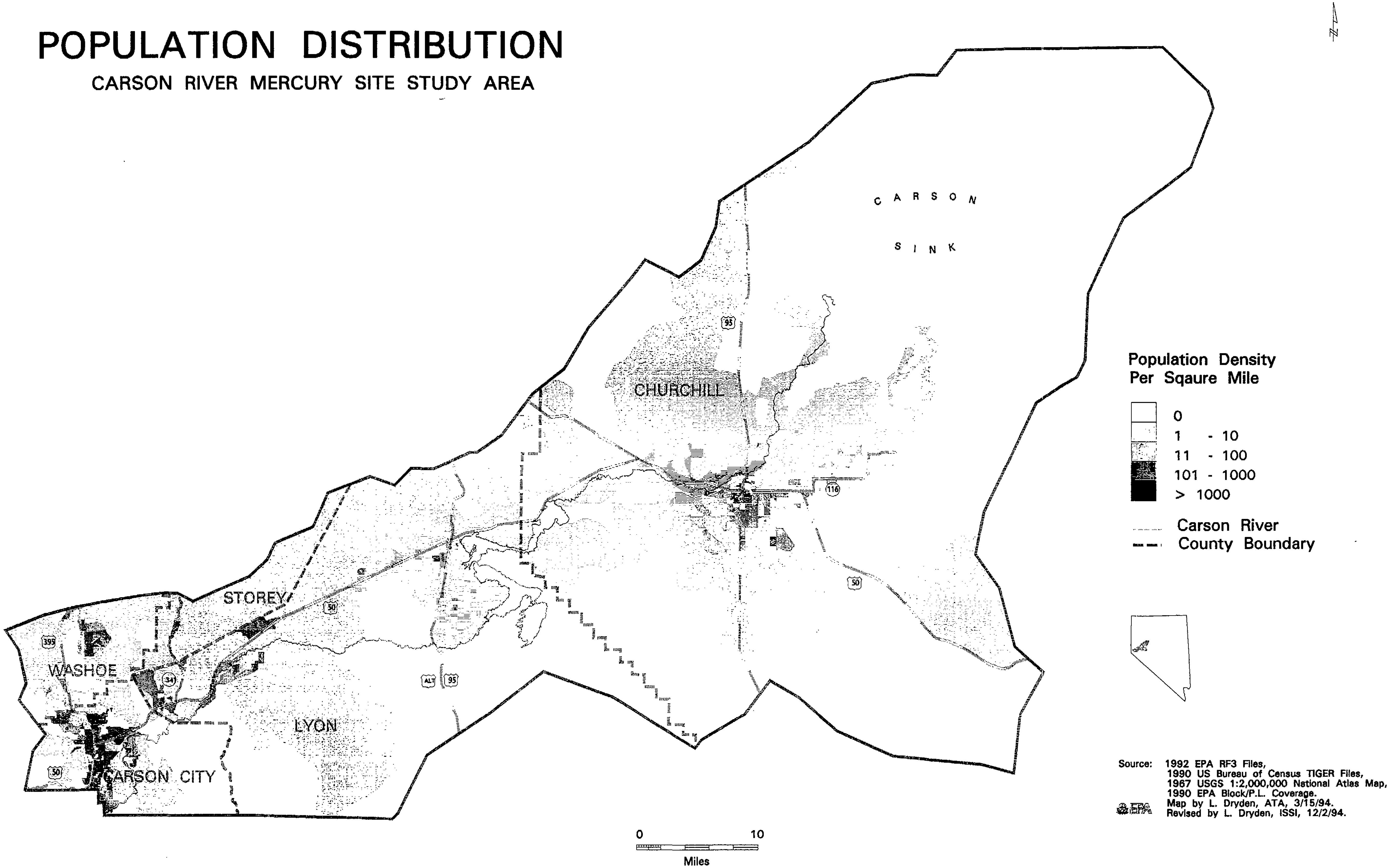
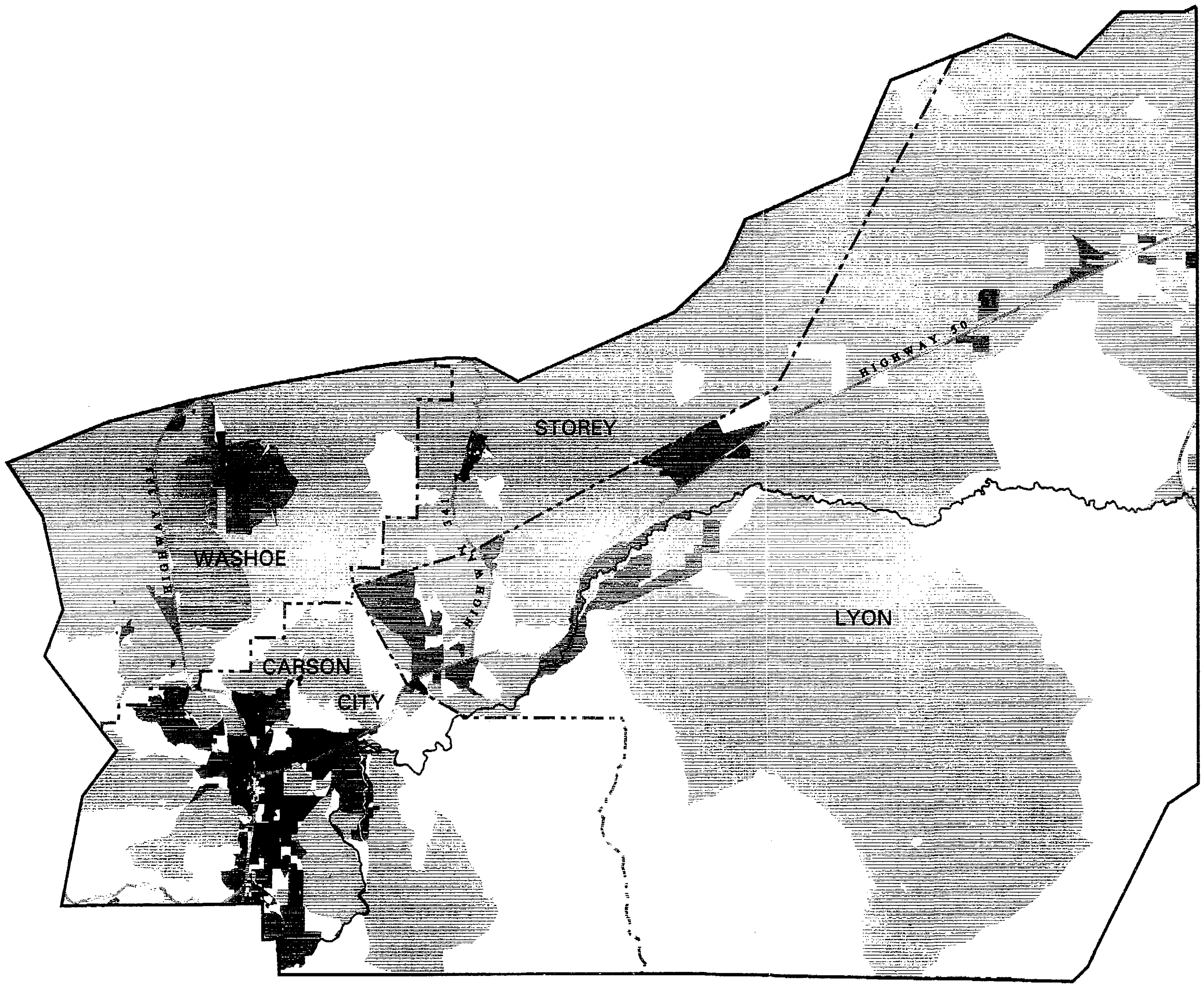


FIGURE 7



POPULATION DISTRIBUTION

CARSON RIVER MERCURY SITE
WESTERN REGION

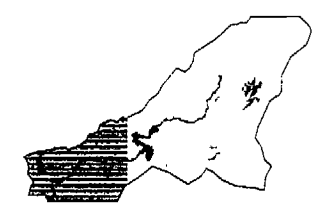
Population Density
Per Square Mile

- 0
- 1 - 10
- 11 - 100
- 101 - 1000
- > 1000

Washoe Lake

Carson River
County Boundary

0 5
Miles



Source: 1992 EPA RF3 Files,
1990 US Bureau of Census TIGER Files,
1967 USGS 1:2,000,000 National Atlas Map,
1990 EPA Block/P.L. Coverage.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/2/94.

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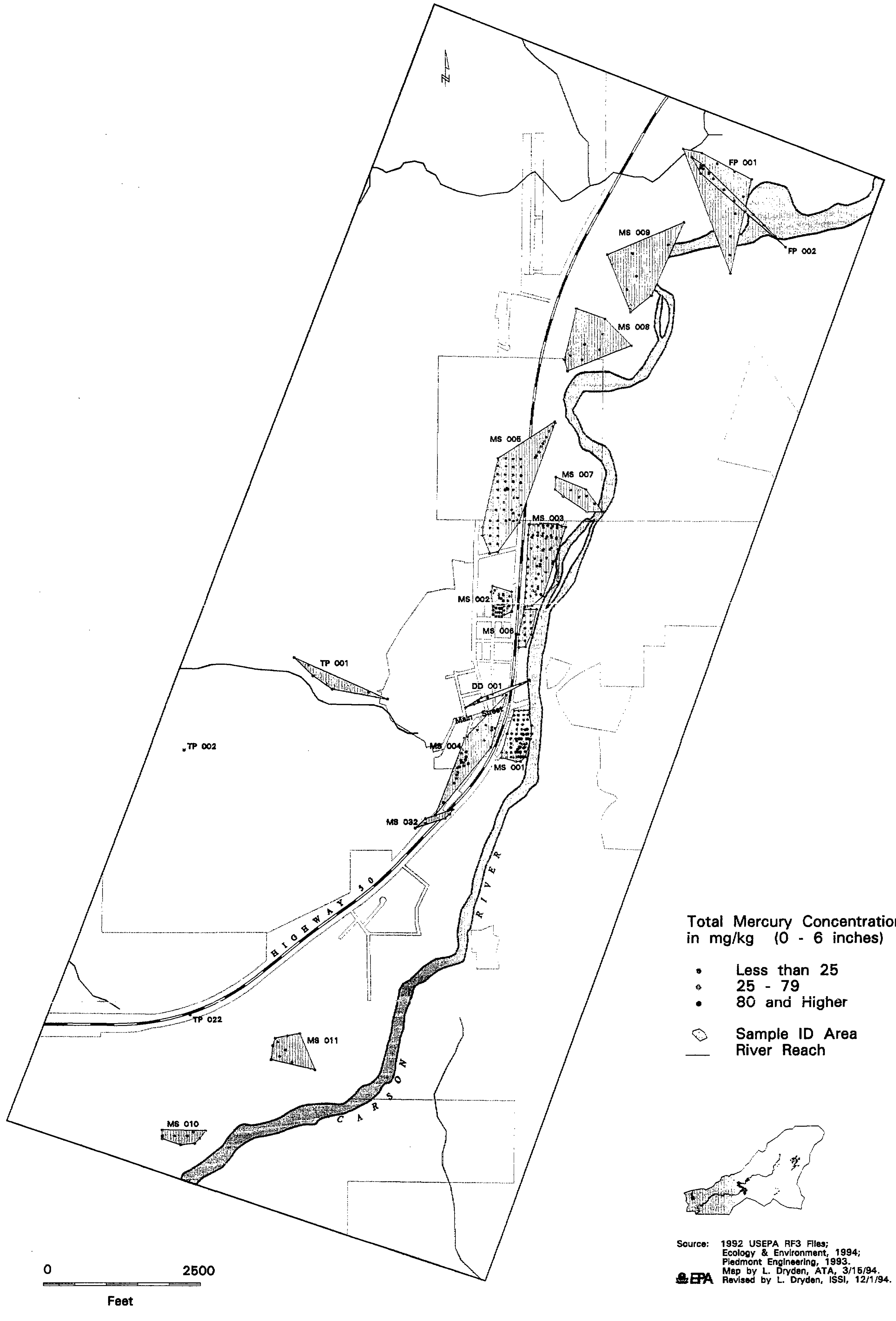
FIGURE 8

SURFACE SOIL SAMPLING LOCATIONS

DAYTON



Total Mercury Concentration in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

Sample ID Area

River Reach

Source: 1992 USEPA RF3 Files; Ecology & Environment, 1994; Piedmont Engineering, 1993. Map by L. Dryden, ATA, 3/15/94. Revised by L. Dryden, ISSI, 12/1/94.

EPA

FIGURE 9

SUB-AREAS OF POTENTIAL CONCERN
DAYTON

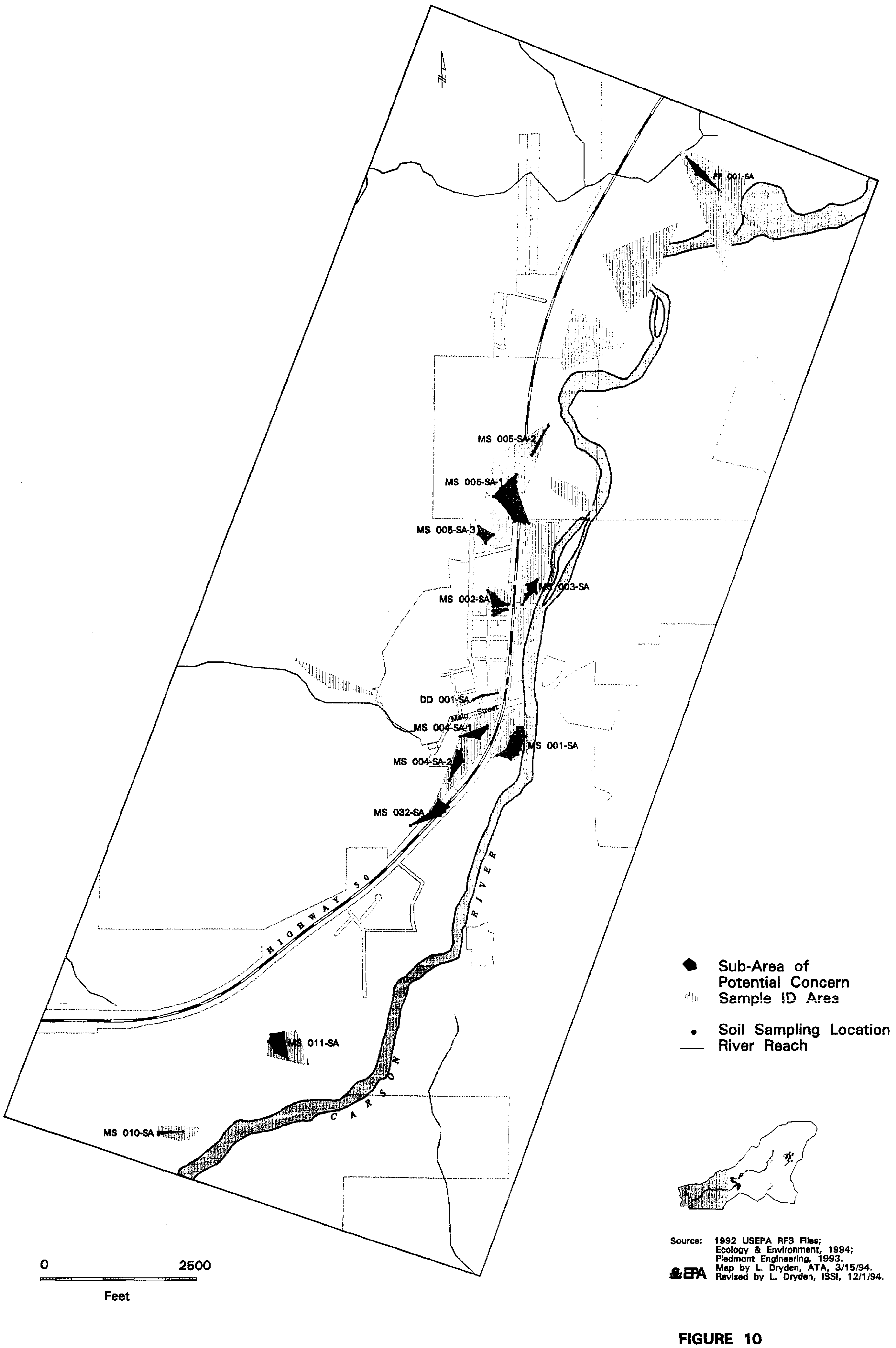
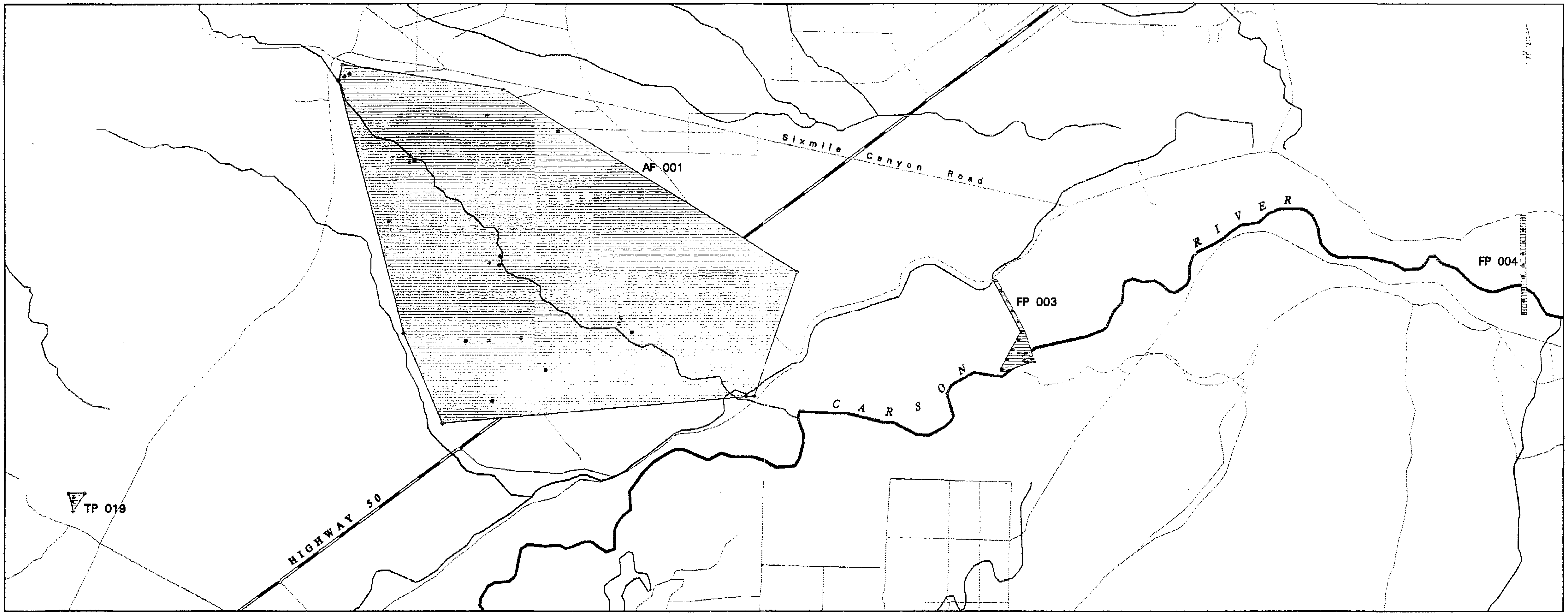
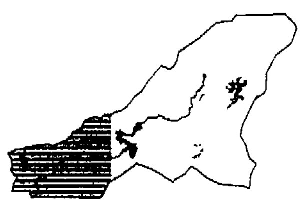


FIGURE 10



SURFACE SOIL SAMPLING LOCATIONS

ALLUVIAL FAN AND FLOOD PLAIN



Source: 1992 USEPA RR3 Files;
Ecology & Environment, 1994;
1992 US Bureau of Census TIGER Files.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

EPA

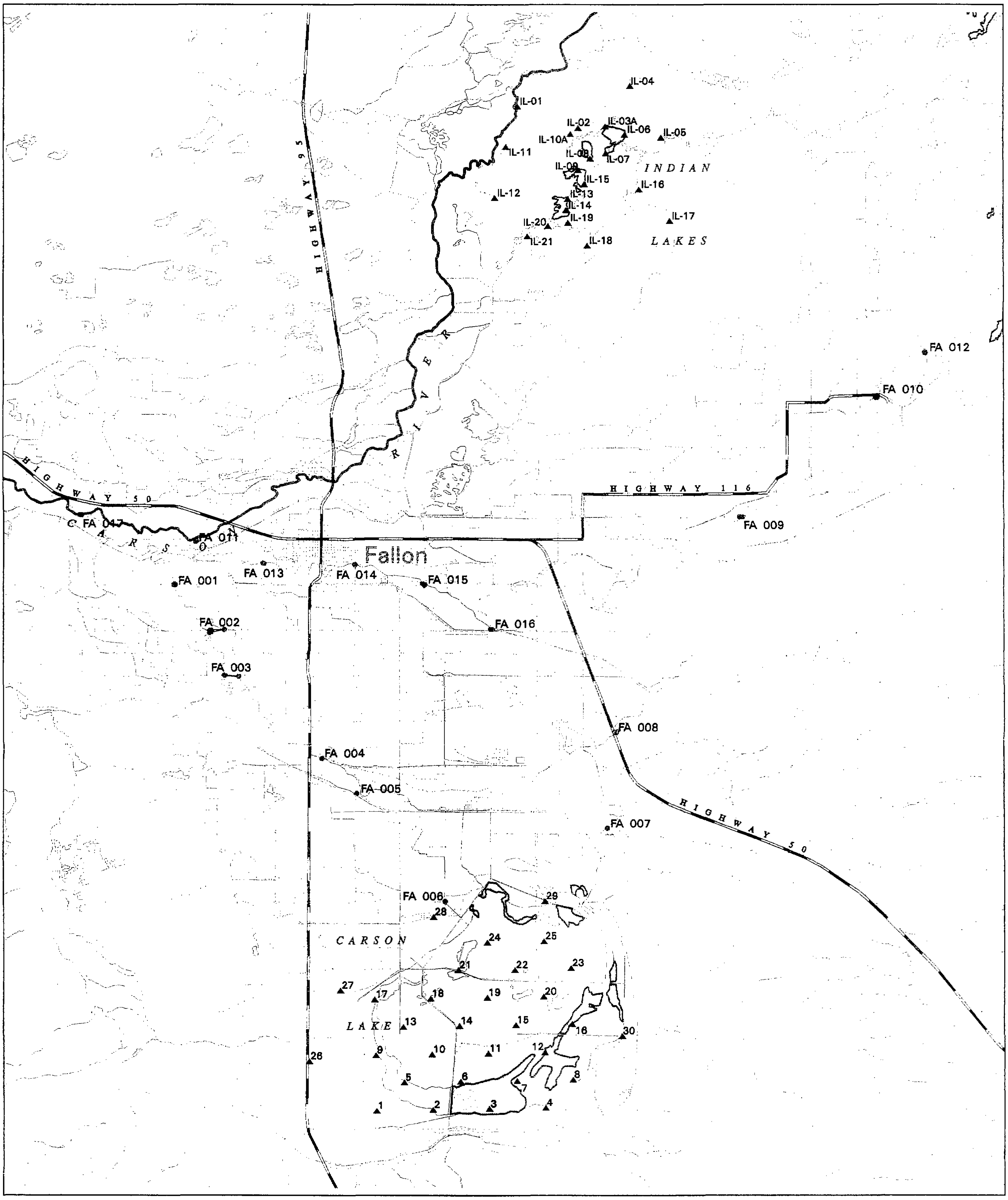
0 — 1
Mile

Total Mercury Concentration in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

Sample ID Area
River Reach

FIGURE 11



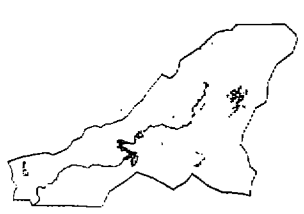
SURFACE SOIL AND SEDIMENT SAMPLING LOCATIONS

BELOW LAHONTAN DAM

Total Mercury Concentration in mg/kg (0 - 6 inches) for EPA Sample Locations

- Less than 25
- 25 - 79
- 80 and Higher

▲ U.S.B.R Sample Location
— River Reach

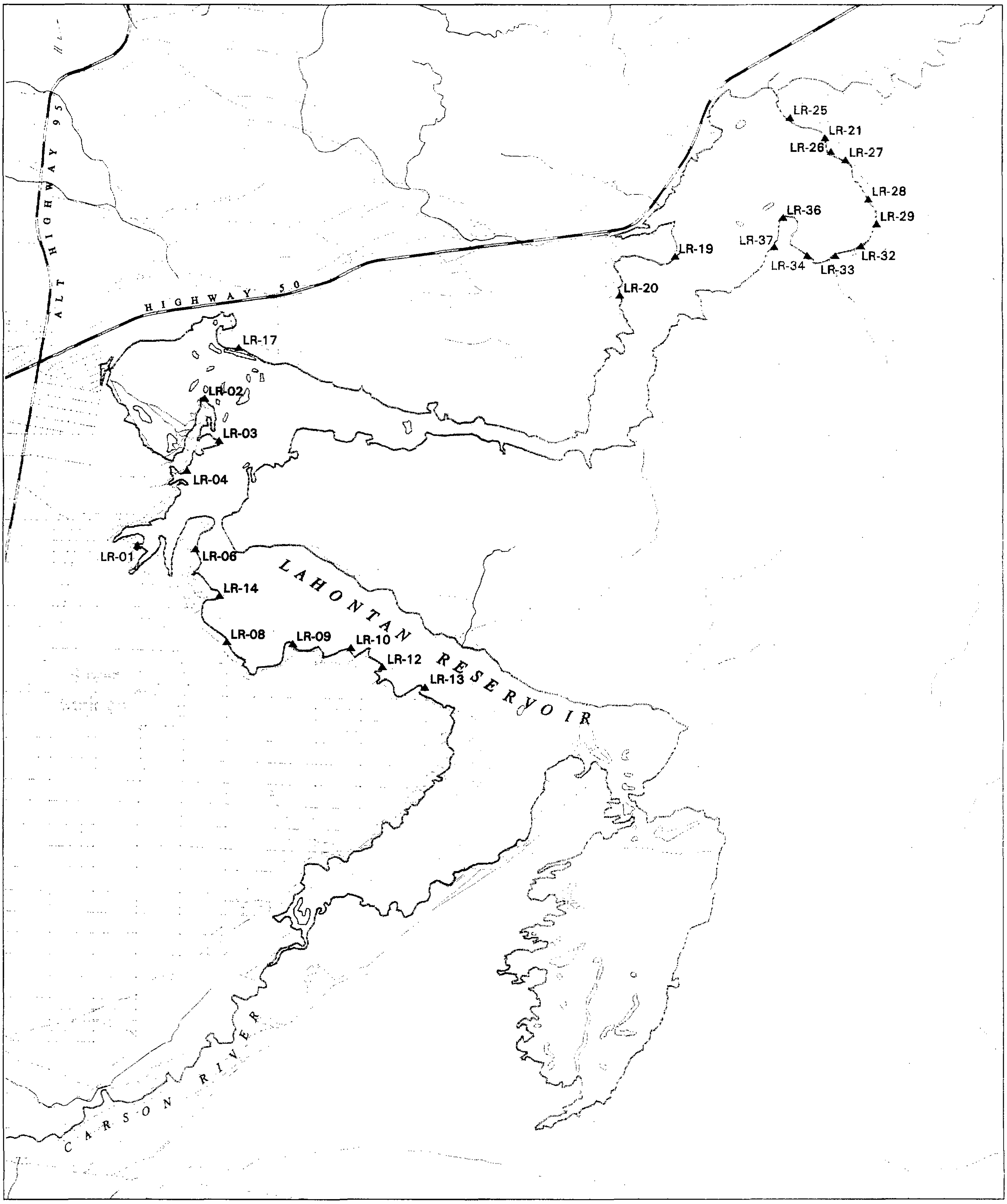


0 2
Miles

Source: Ecology & Environment, 1994; US Bureau of Reclamation, 1993; 1990 US Bureau of Census TIGER Files. Map by L. Dryden, ATA, 3/15/94. Revised by L. Dryden, ISSI, 12/1/94.

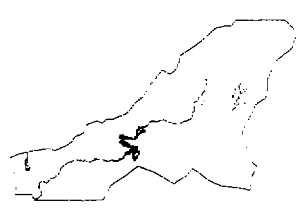
EPA

FIGURE 12



U.S.B.R. SOIL SAMPLING LOCATIONS

LAHONTAN RESERVOIR RECREATION AREA



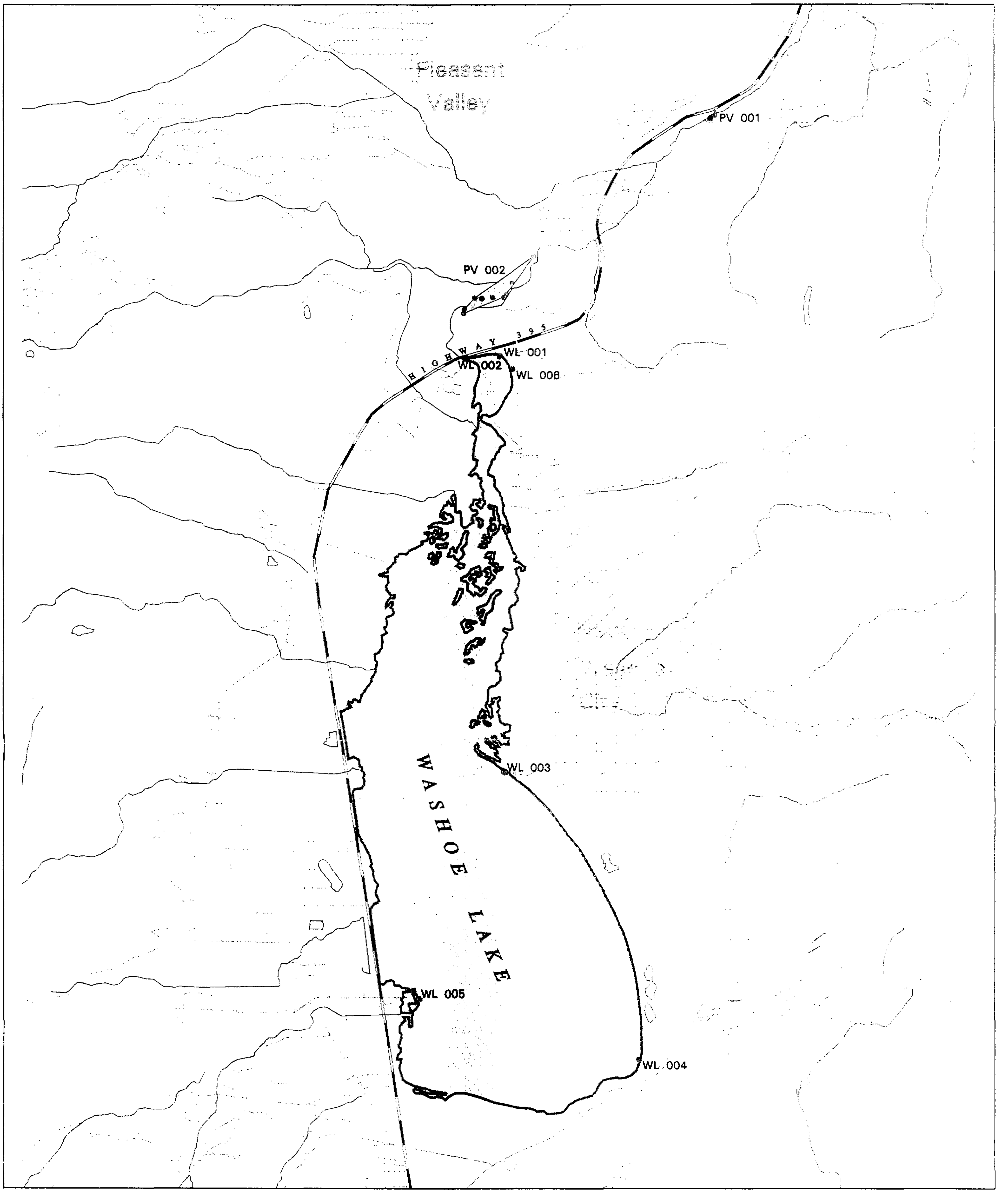
River Reach

0 2
Miles

Source: US Bureau of Reclamation, 1993;
1990 US Bureau of Census TIGER Files.
Map by L. Dryden, ATA, 2/28/94.

EPA

FIGURE 13



SURFACE SOIL SAMPLING LOCATIONS

WASHOE LAKE RECREATION AREA

Total Mercury Concentration in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

Sample ID Area
River Reach

0 2
Miles

Source: 1992 USEPA RF3 Files; Ecology & Environment, 1994; Piedmont Engineering, 1993. Map by L. Dryden, ATA, 3/15/94.

EPA

FIGURE 14

AIR AND GROUNDWATER SAMPLING LOCATIONS

DAYTON

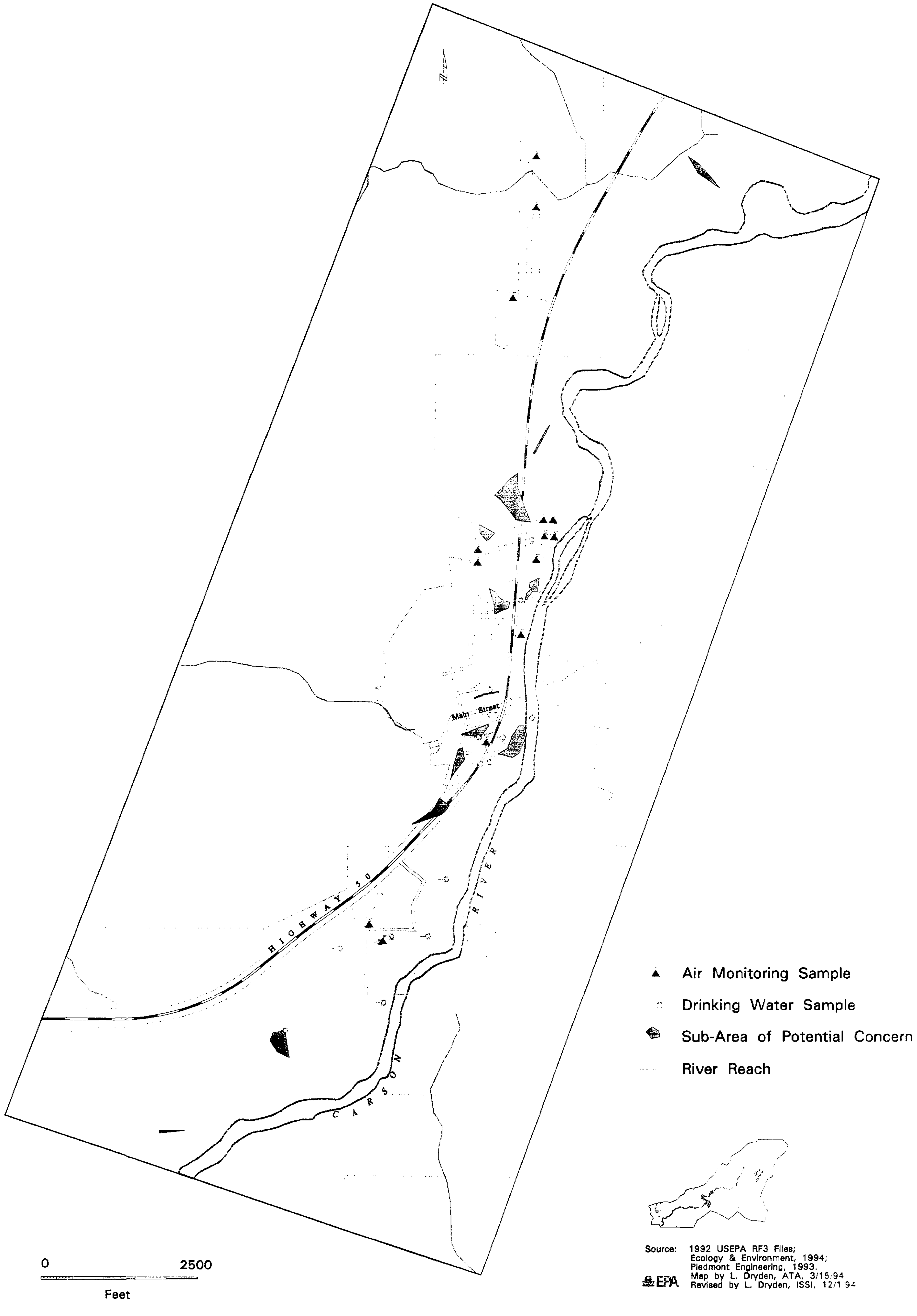
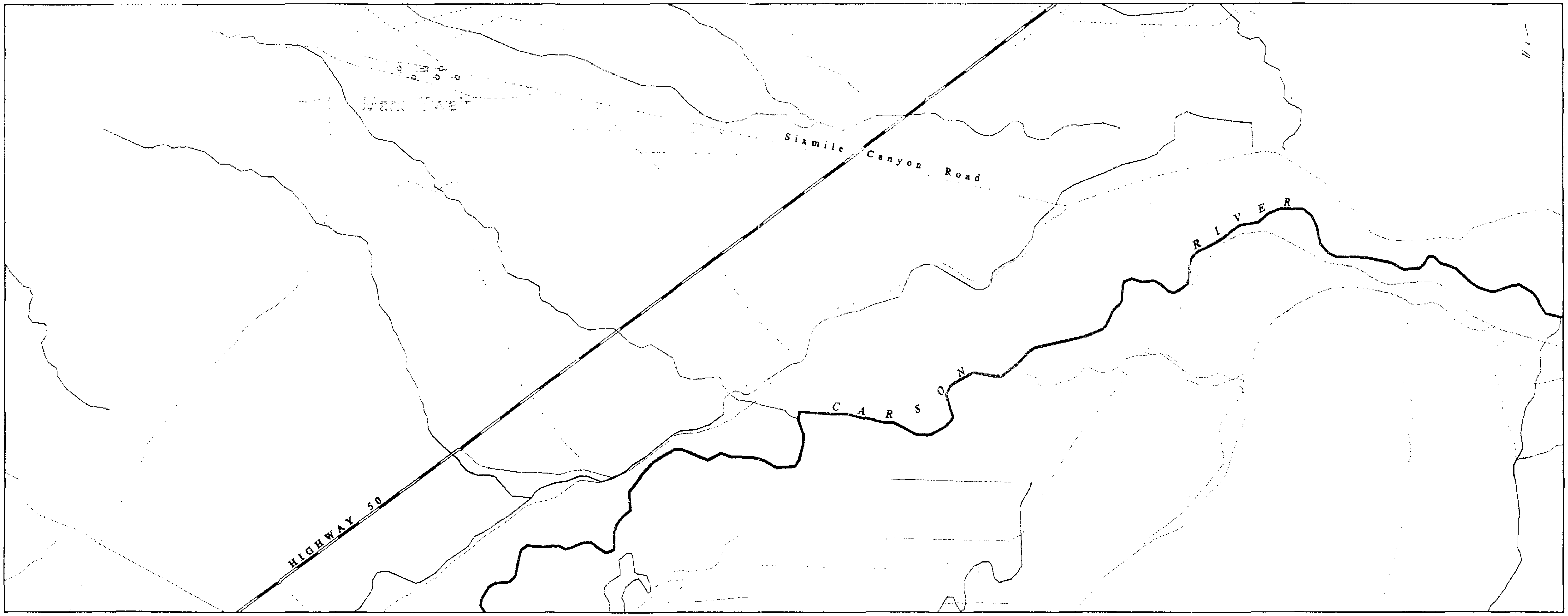
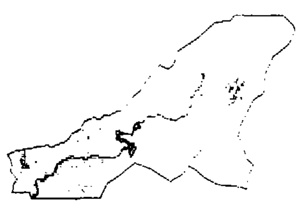


FIGURE 15



GROUNDWATER SAMPLING LOCATIONS

ALLUVIAL FAN AND FLOOD PLAIN



Drinking Water Sample

River Reach

0 1

Mile

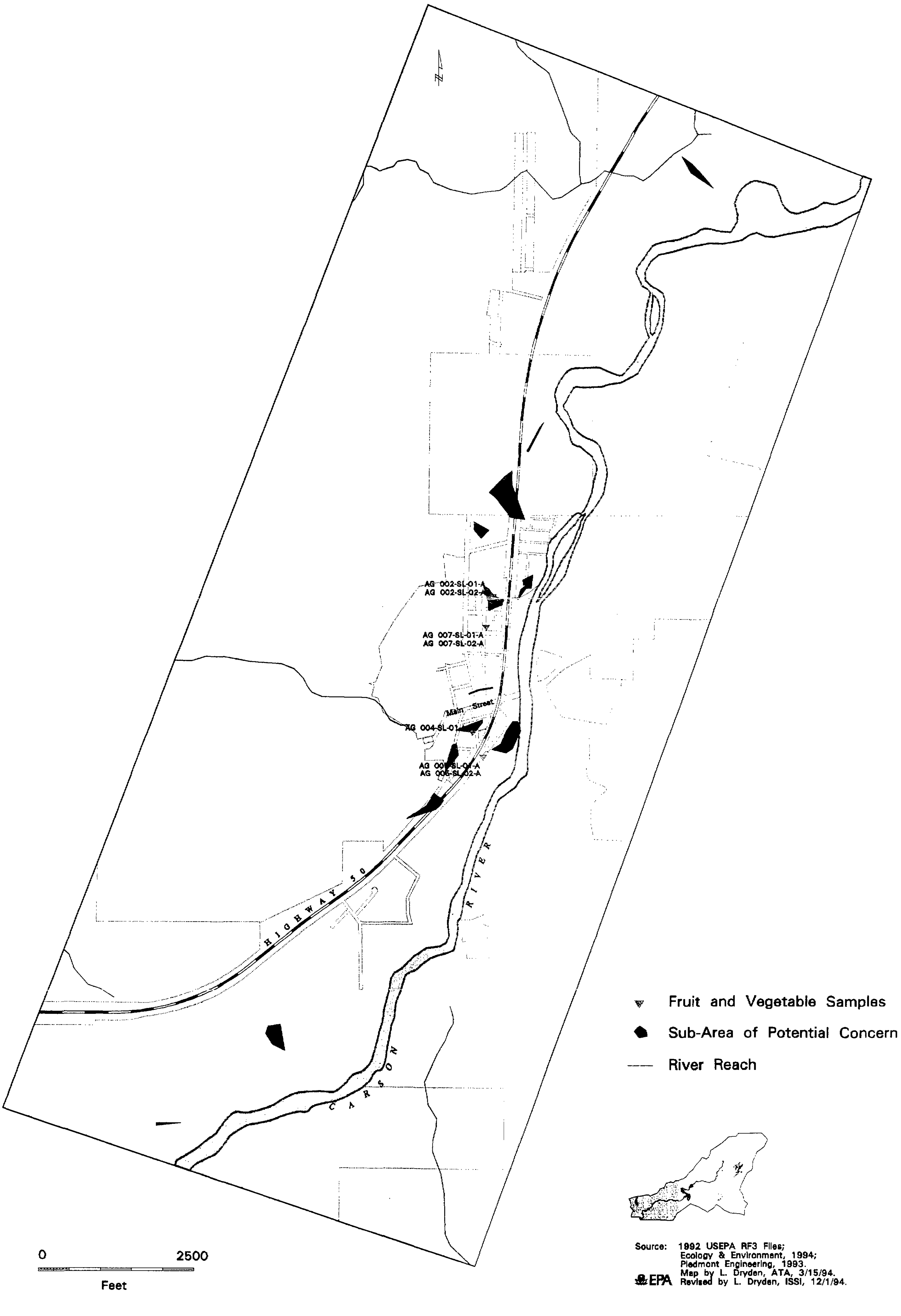
Source: 1992 USEPA RR3 Files;
Ecology & Environment, 1994;
1992 US Bureau of Census TIGER Files.
Map by L. Dryden, ATA, 3/15/94.

EPA

FIGURE 16

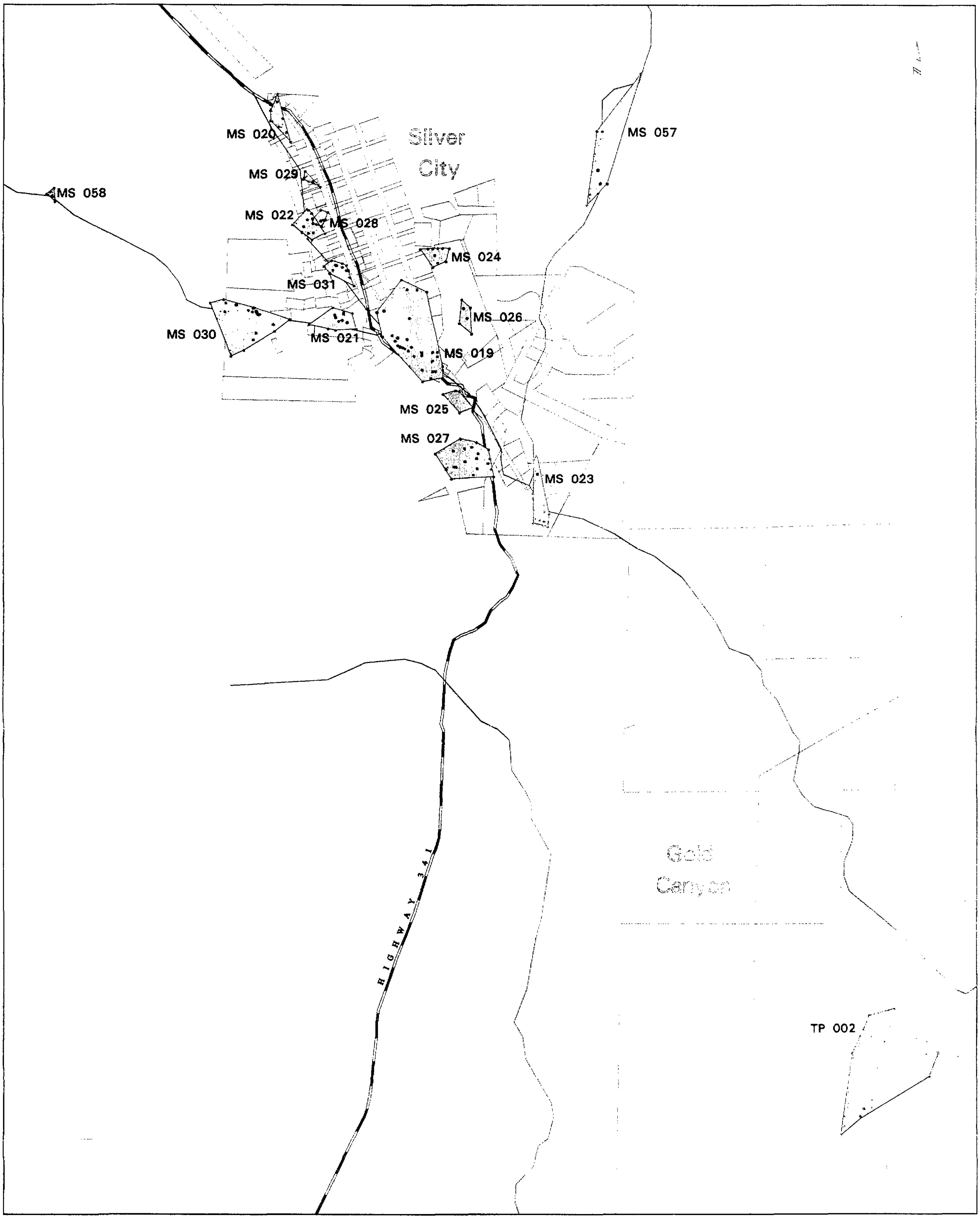
GARDEN SAMPLING LOCATIONS

DAYTON



Source: 1992 USEPA RF3 Files;
Ecology & Environment, 1994;
Piedmont Engineering, 1993.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

FIGURE 17



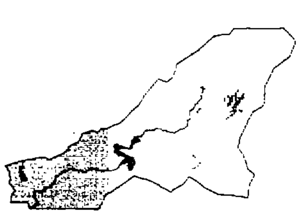
SURFACE SOIL SAMPLING LOCATIONS

SILVER CITY

Total Mercury Concentration in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

Sample ID Area
River Reach

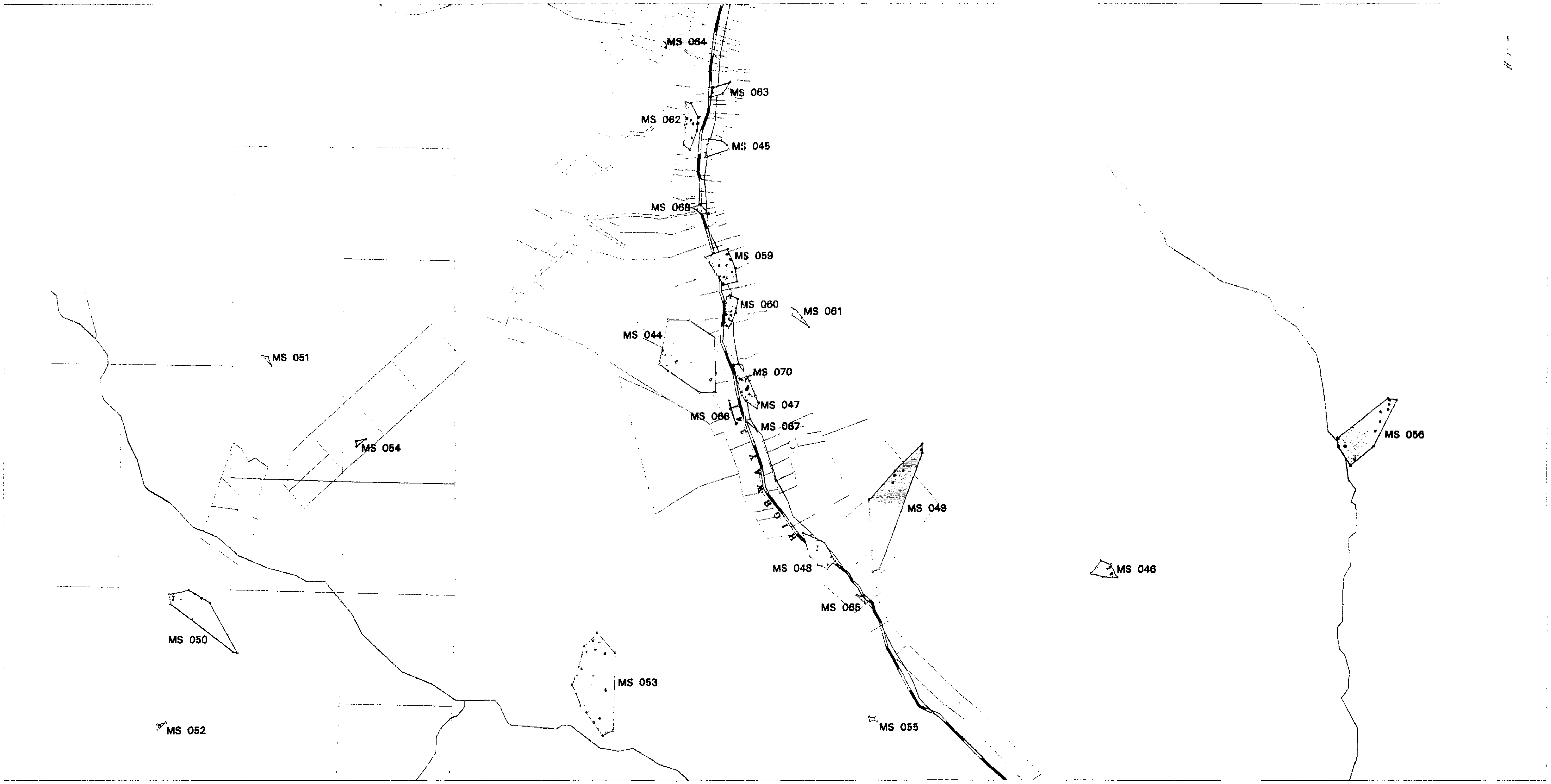


Source: 1992 USEPA RF3 Files; Ecology & Environment, 1994; Piedmont Engineering, 1993. Map by L. Dryden, ATA, 3/15/94. Revised by L. Dryden, ISSI, 12/1/94.

EPA

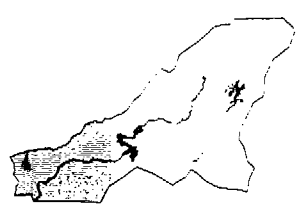
0 2000
Feet

FIGURE 18



SURFACE SOIL SAMPLING LOCATIONS

GOLD HILL AND AMERICAN FLAT



Total Mercury Concentration in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

Sample ID Area

River Reach

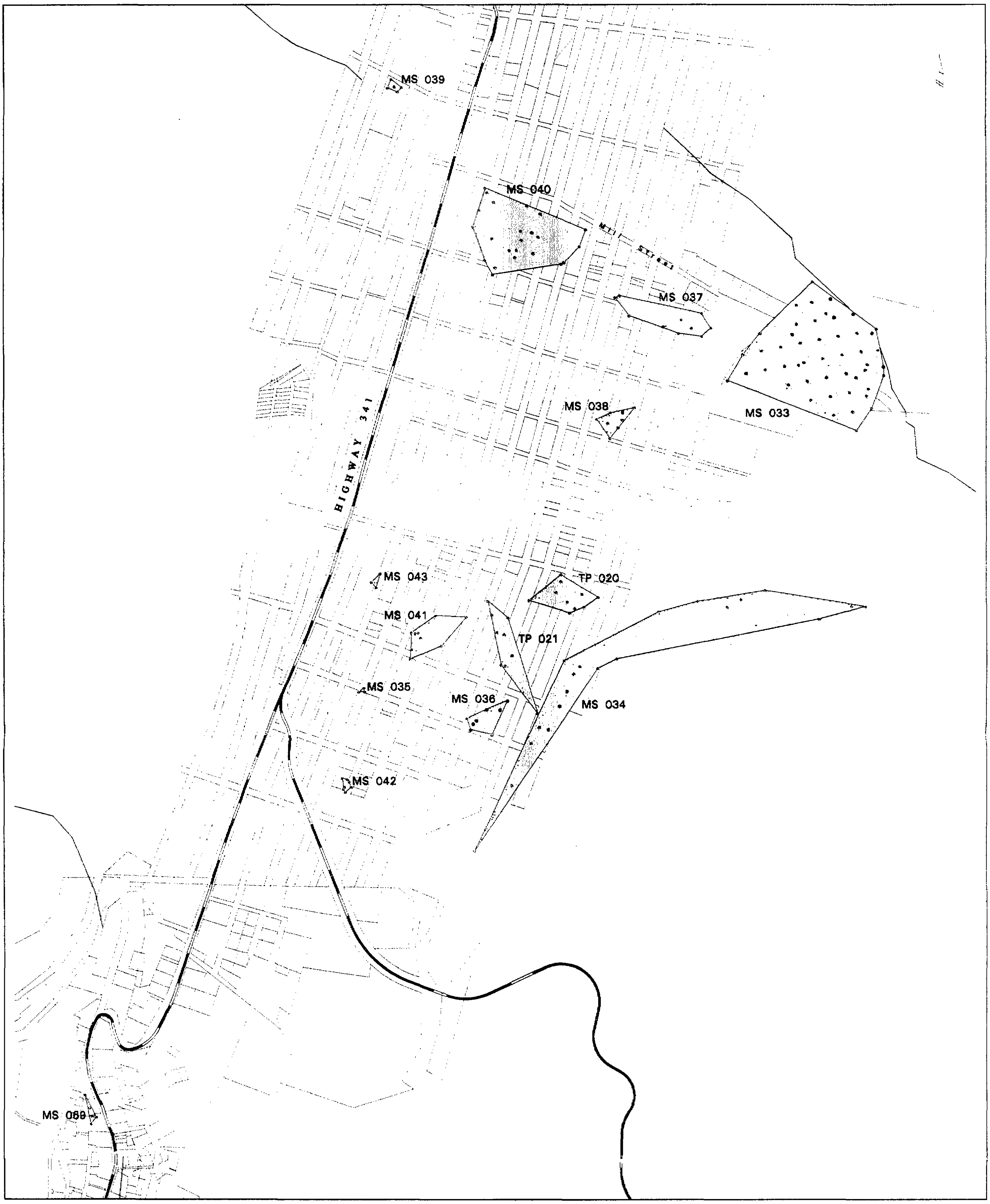
0 2000

Feet

Source: 1992 USEPA RF3 Files; Ecology & Environment, 1994; Piedmont Engineering, 1993. Map by L. Dryden, ATA, 3/15/94. Revised by L. Dryden, ISSI, 12/1/94.

EPA

FIGURE 19



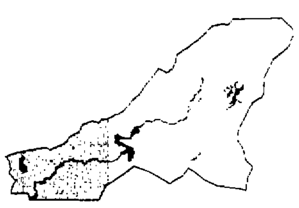
SURFACE SOIL SAMPLING LOCATIONS

VIRGINIA CITY

Total Mercury Concentration in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

Sample ID Area
River Reach

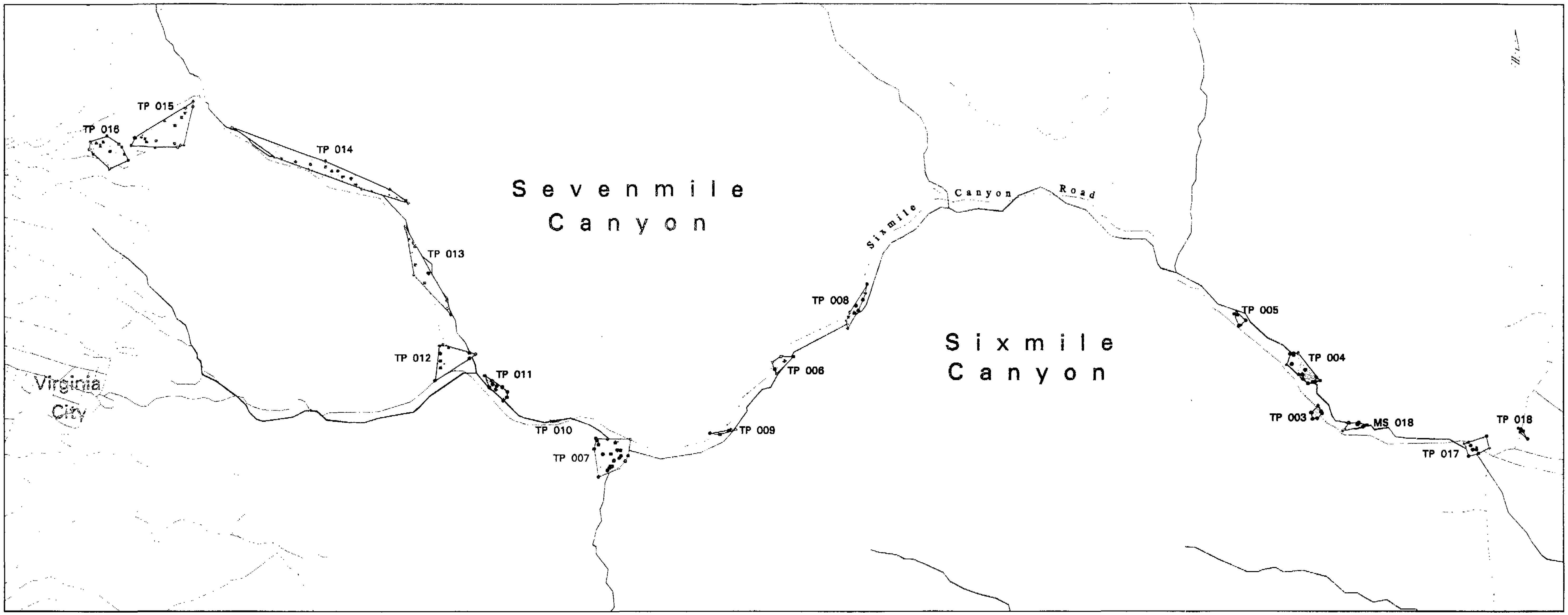


0 1000
Feet

Source: 1992 USEPA RF3 Files;
Ecology & Environment, 1994;
Piedmont Engineering, 1993.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

EPA

FIGURE 20



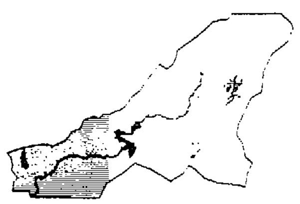
SURFACE SOIL SAMPLING LOCATIONS

SIXMILE CANYON

Total Mercury Concentration in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

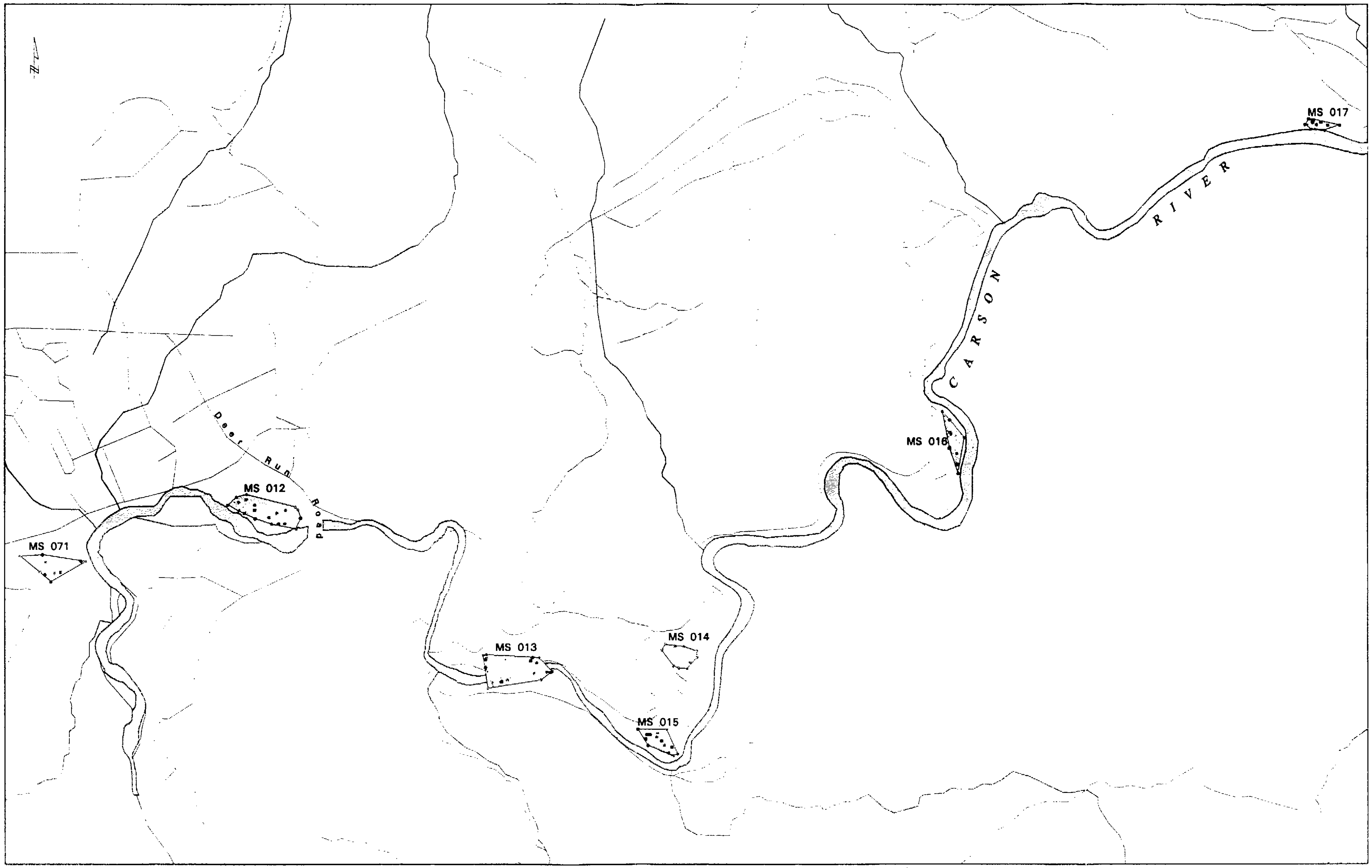
Sample ID Area
River Reach



0 2500
Feet

Source: 1992 USEPA RF3 Files;
Ecology & Environment, 1994;
1992 US Bureau of Census TIGER Files.
EPA Map by L. Dryden, ATA, 3/15/94.

FIGURE 21



SURFACE SOIL SAMPLING LOCATIONS

FLOOD PLAIN BETWEEN NEW EMPIRE - DAYTON

Total Mercury Concentration
in mg/kg (0 - 6 inches)

- Less than 25
- 25 - 79
- 80 and Higher

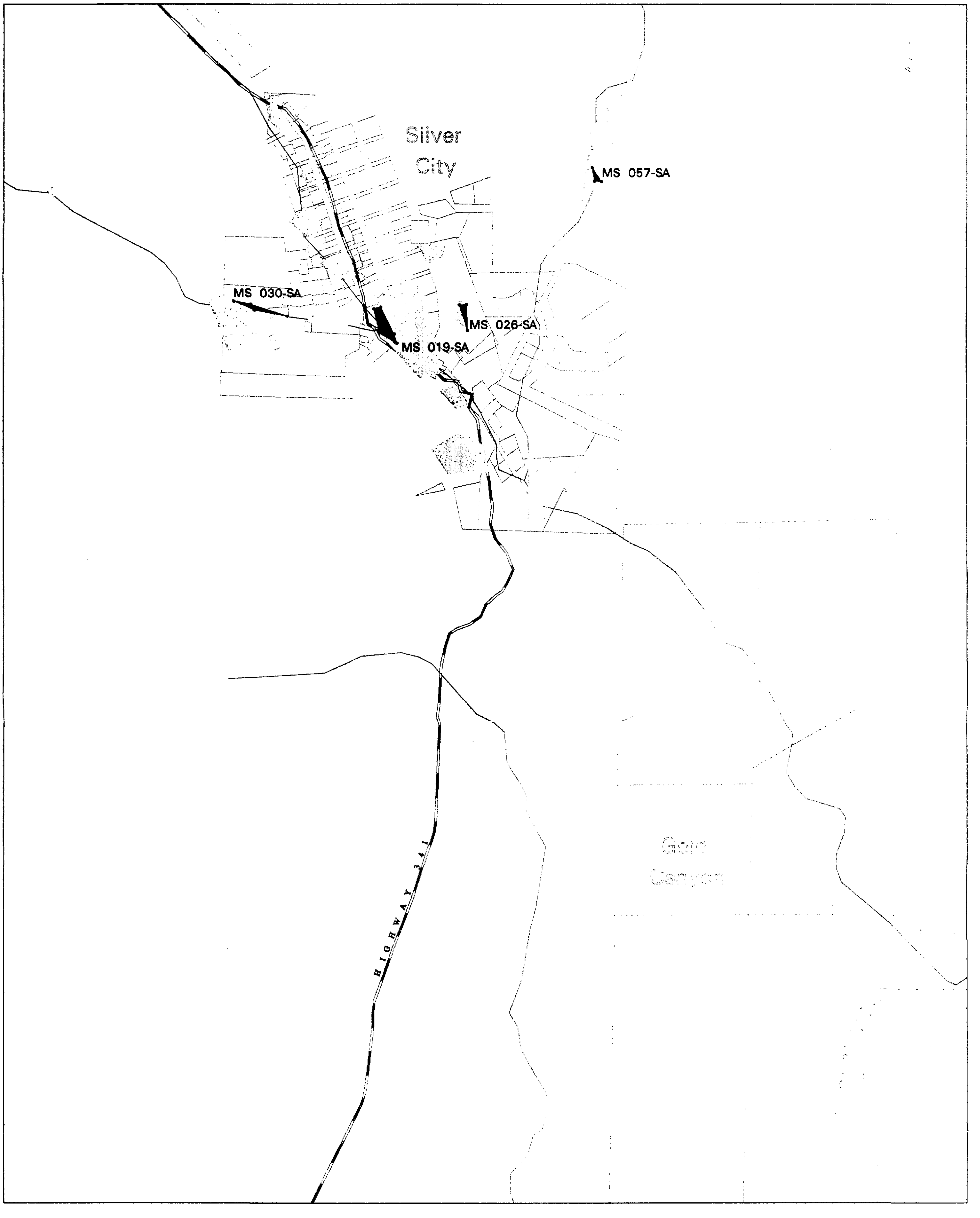
Sample ID Area
River Reach

0 2500
Feet

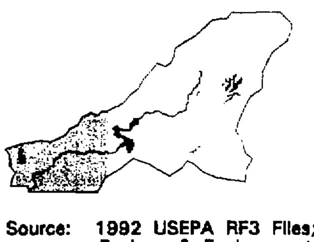
Source: 1992 USEPA RF3 Files;
Ecology & Environment, 1994,
Piedmont Engineering, 1993;
1992 US Bureau of Census TIGER Files.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

EPA

FIGURE 22



SUB-AREAS OF POTENTIAL CONCERN
SILVER CITY



Source: 1992 USEPA RF3 Files;
Ecology & Environment, 1994;
Piedmont Engineering, 1993.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

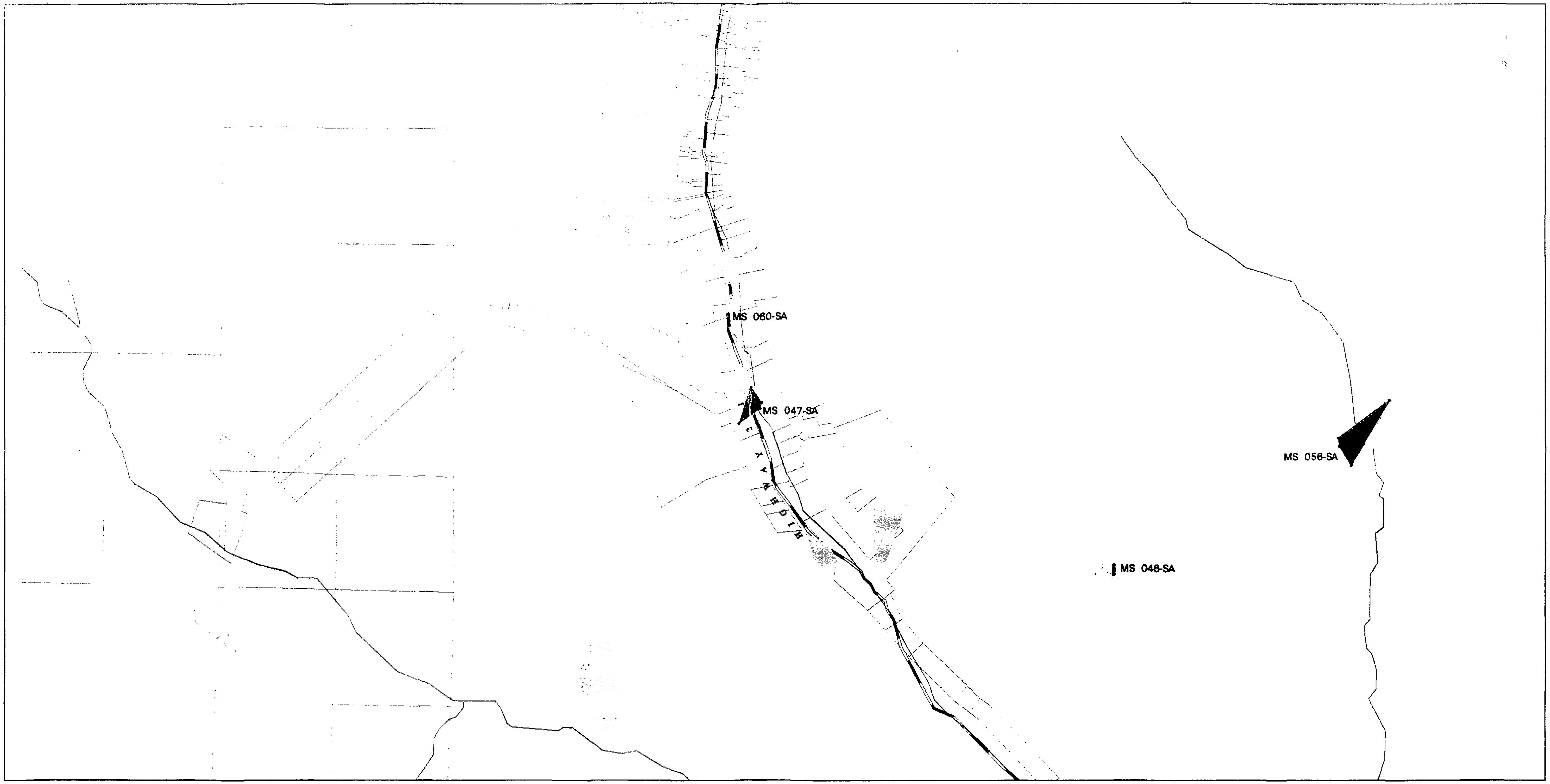
EPA

0 2000
Feet

Sub-Area of Potential Concern
Sample ID Area

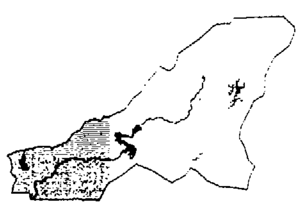
• Soil Sampling Location
— River Reach

FIGURE 23



SUB-AREAS OF POTENTIAL CONCERN

GOLD HILL AND AMERICAN FLAT



Source: 1992 USEPA RF3 Files;
Ecology & Environment, 1994;
Piedmont Engineering, 1993.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

EPA

0 2000

Feet

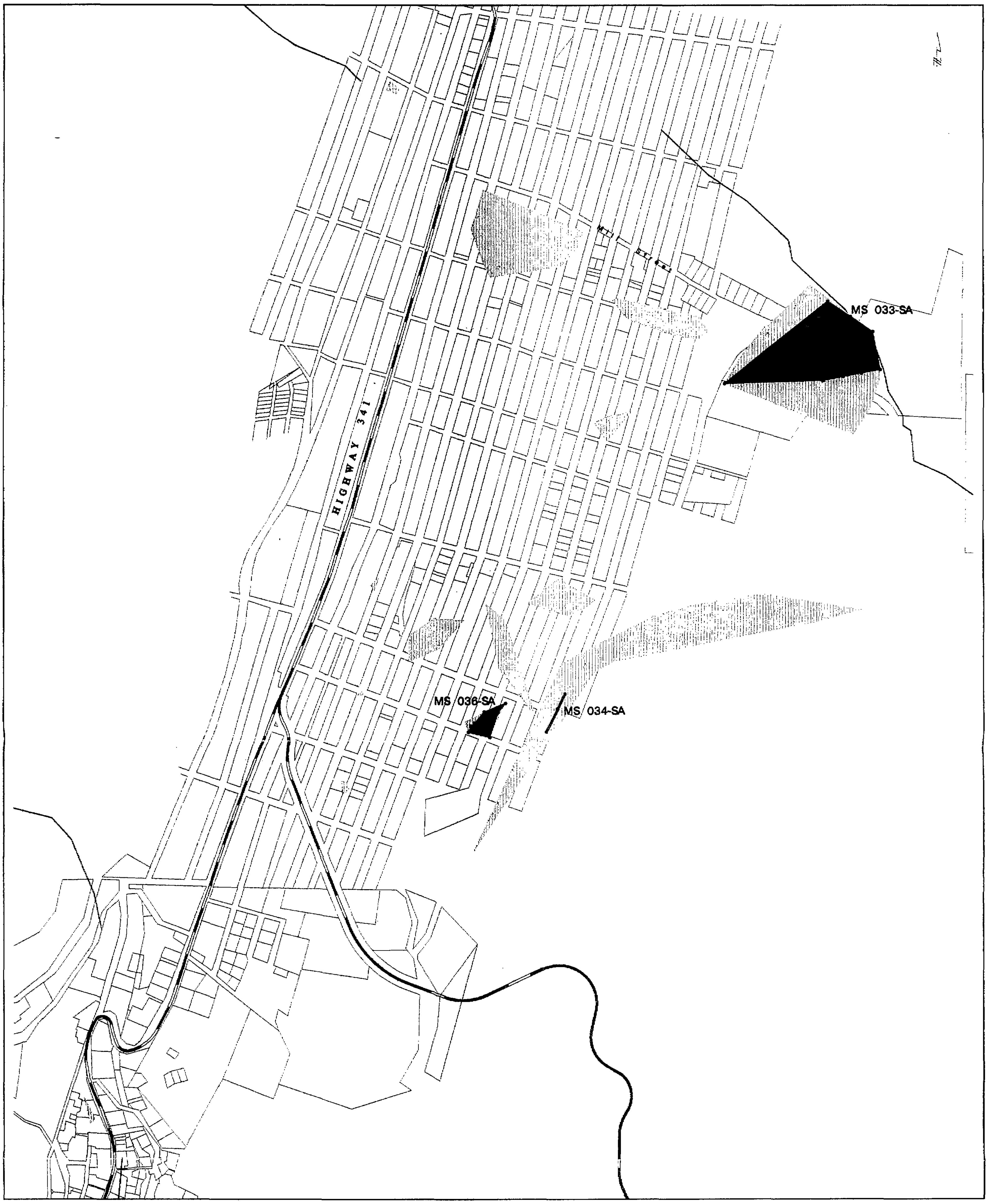
Sub-Area of Potential Concern

Sample ID Area

Soil Sampling Location

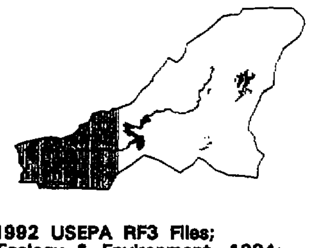
River Reach

FIGURE 24



SUB-AREAS OF POTENTIAL CONCERN

VIRGINIA CITY



- Sub-Area of Potential Concern
- Sample ID Area
- Soil Sampling Location
- River Reach

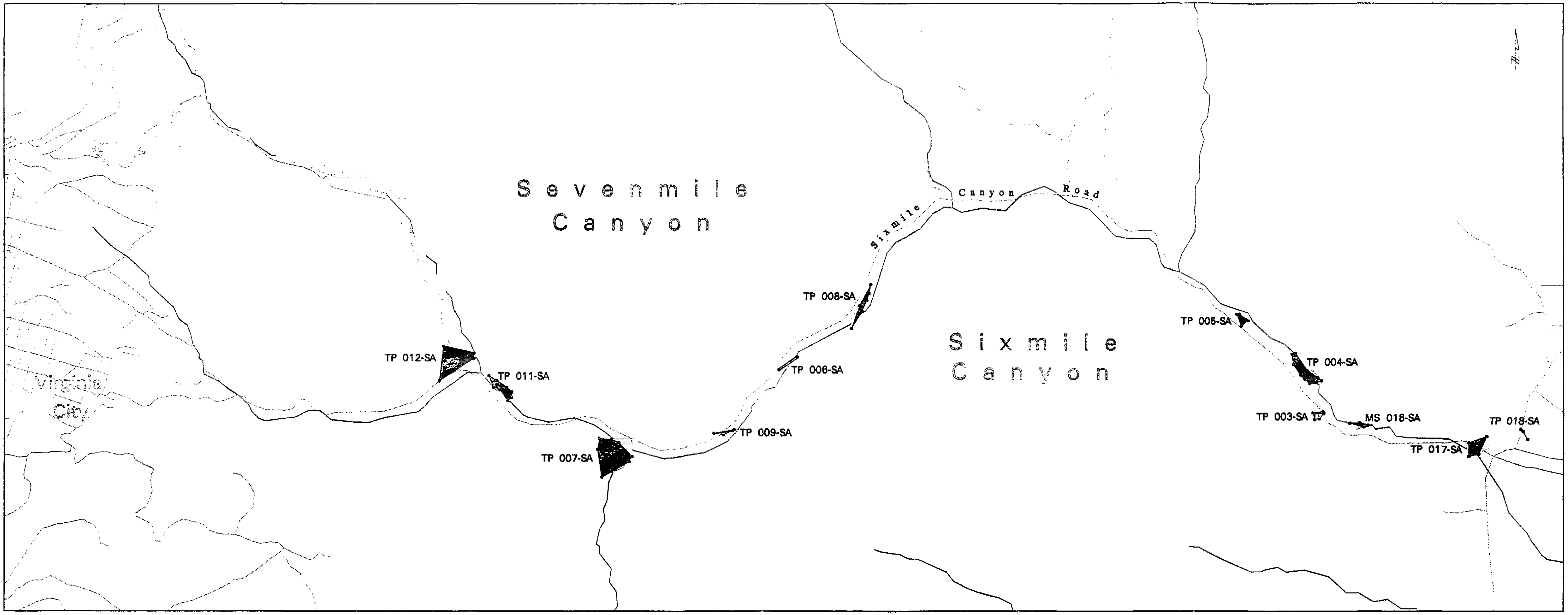
0 1000

Feet

Source: 1992 USEPA RF3 Files; Ecology & Environment, 1994; Piedmont Engineering, 1993. Map by L. Dryden, ATA, 3/15/94. Revised by L. Dryden, ISSI, 12/1/94.

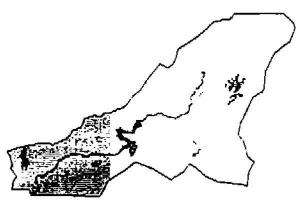
EPA

FIGURE 25



SUB-AREAS OF POTENTIAL CONCERN

SIXMILE CANYON



Sub-Area of Potential Concern

Sample ID Area

Soil Sampling Location

River Reach

0 2500

Feet

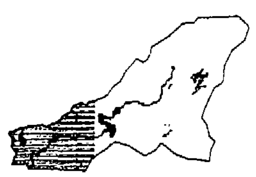
Source: 1992 USEPA RF3 Files; Ecology & Environment, 1994; 1992 US Bureau of Census TIGER Files. Map by L. Dryden, ATA, 3/15/94.

EPA

FIGURE 26

SUB-AREAS OF POTENTIAL CONCERN

FLOOD PLAIN BETWEEN NEW EMPIRE - DAYTON



Source: 1992 USEPA RF3 Files;
Ecology & Environment, 1994;
Piedmont Engineering, 1993;
1992 US Bureau of Census TIGER Files.
Map by L. Dryden, ATA, 3/15/94.
Revised by L. Dryden, ISSI, 12/1/94.

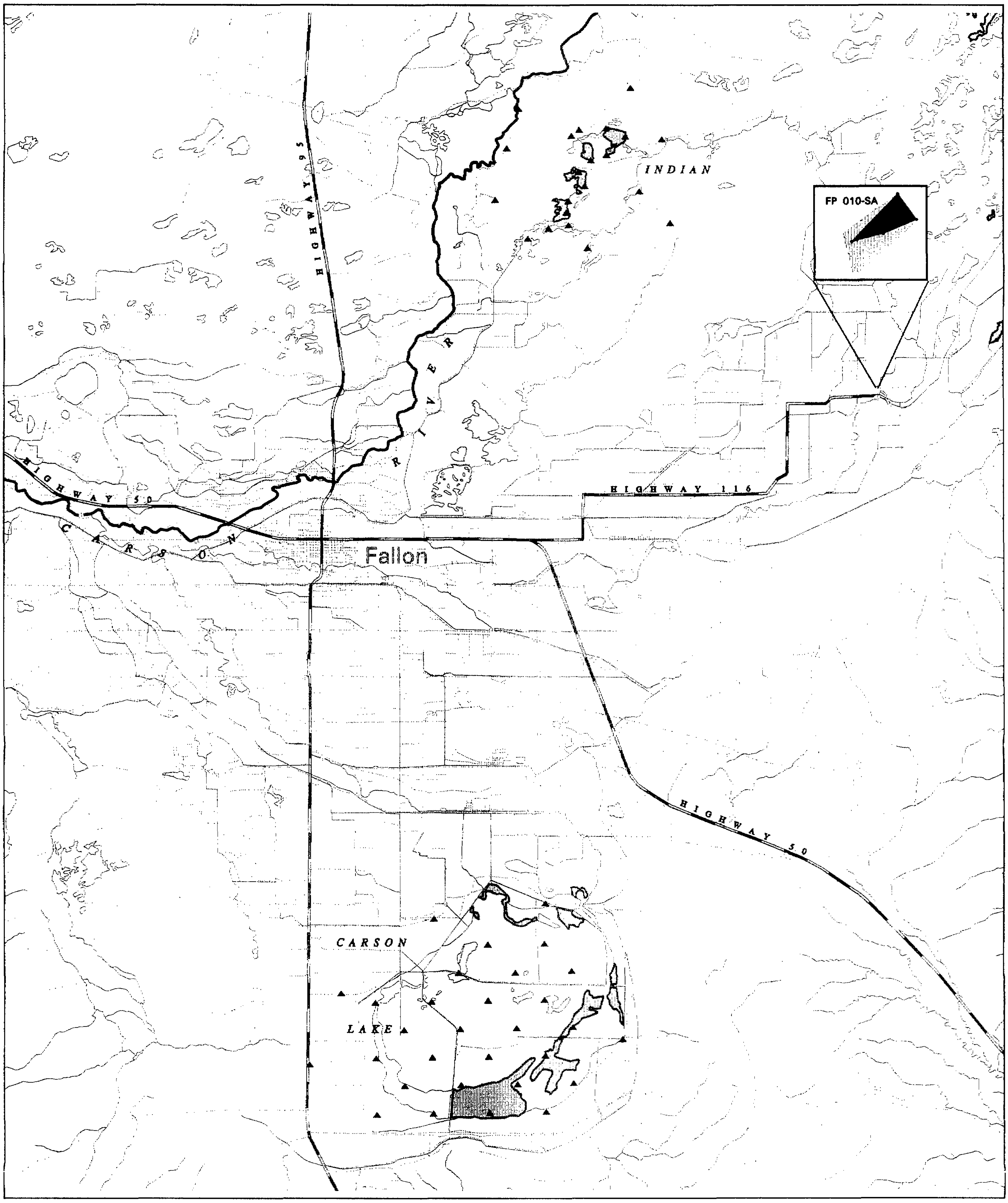
EPA

0 2500

Feet

- Sub-Area of Potential Concern
- Sample ID Area
- Soil Sampling Location
- River Reach

FIGURE 27



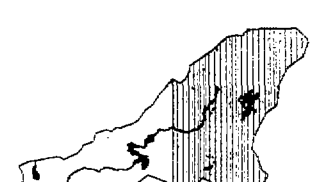
SUB-AREA OF POTENTIAL CONCERN

BELOW LAHONTAN DAM

Sub-Area of Potential Concern
Sample Area

Soil Sampling Location
River Reach

U.S.B.R. Sample Location



Source: Ecology & Environment, 1994; US Bureau of Reclamation, 1993; 1990 US Bureau of Census TIGER Files. Map by L. Dryden, ATA, 3/15/94. Revised by L. Dryden, ISSI, 12/1/94.

EPA

0 2

Miles

FIGURE 28

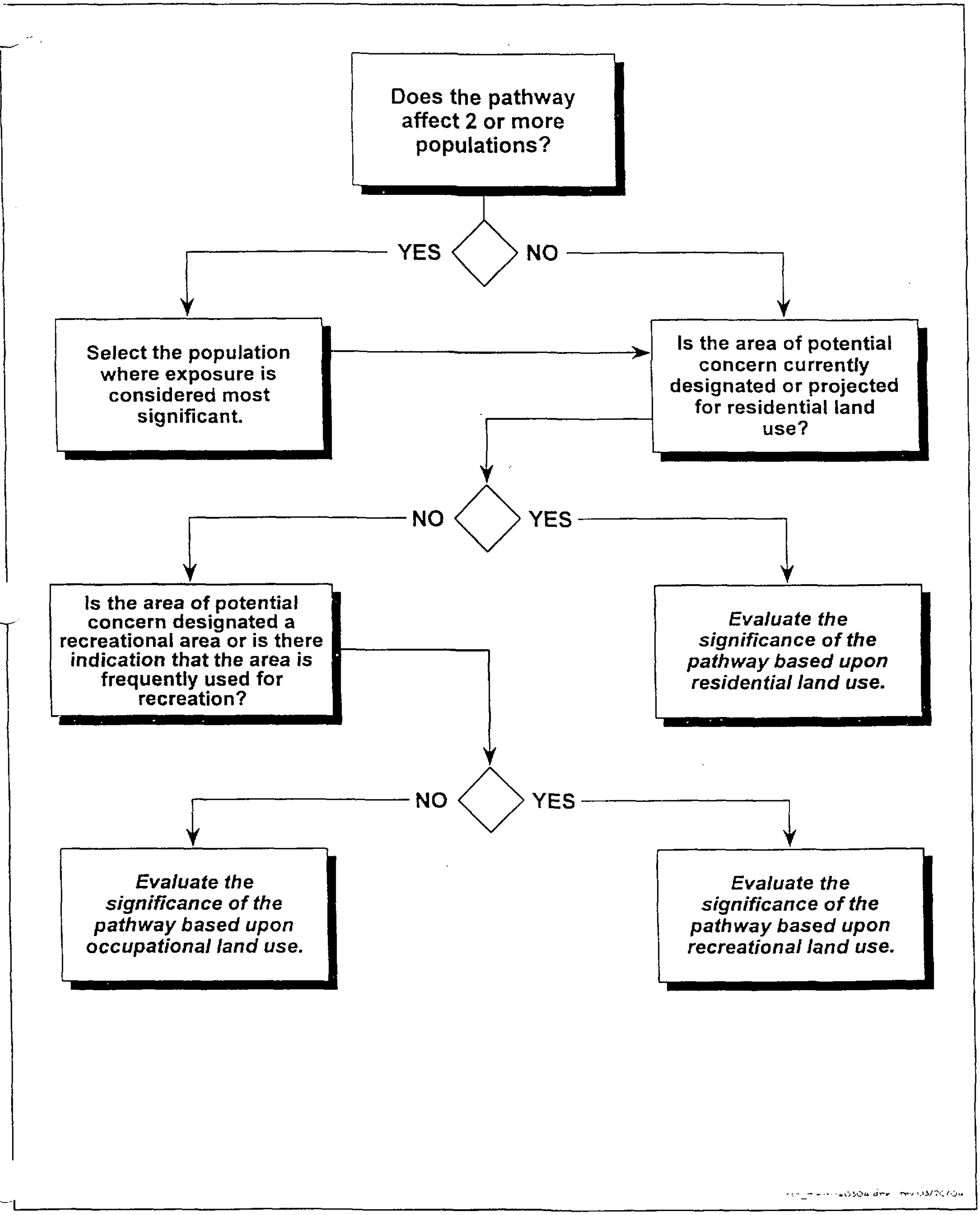


Figure 29: Screening Process for Selecting Population and Land Use for Evaluation

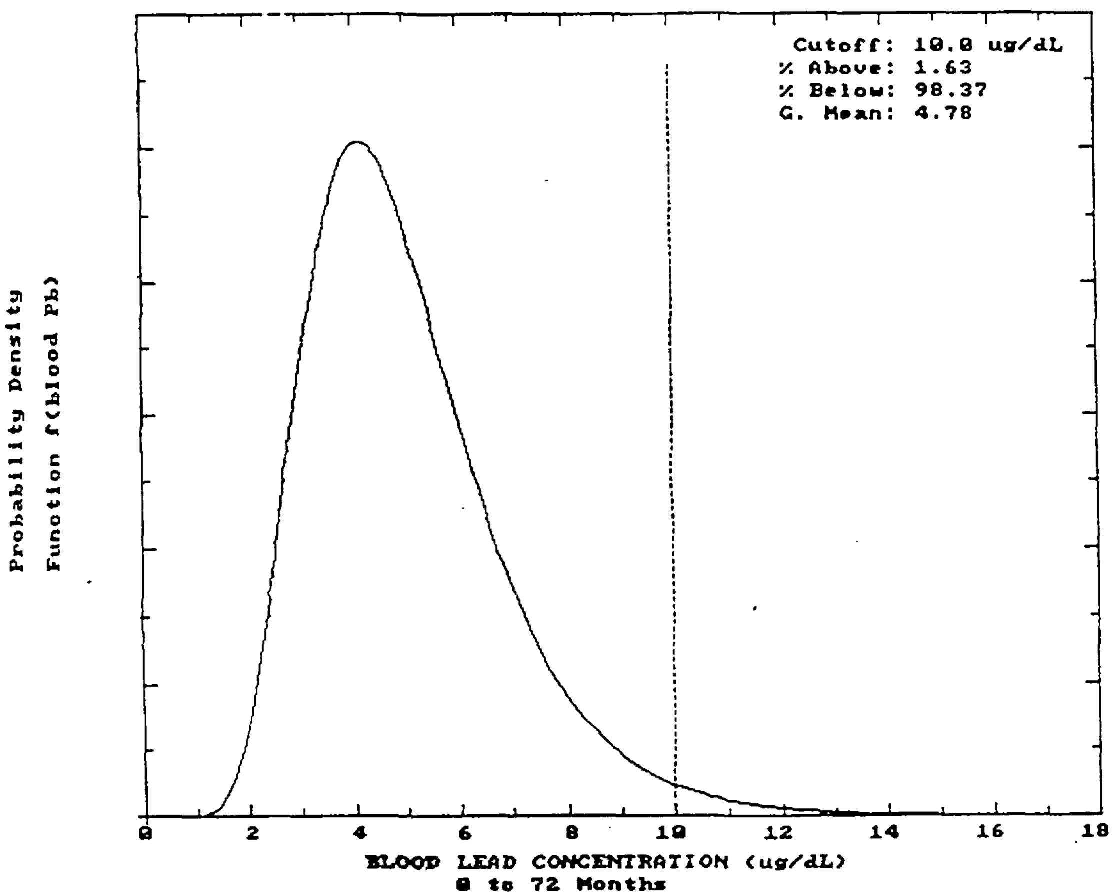


Figure 30: Probability Density Function for Blood Lead